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THESIS

FURTHER DEVELOPMENTS OF FILMWISE CONDENSATION OF STEAM ON HORIZONTAL INTEGRAL FINNED TUBES

by

Mark Brady Guttendorf

June 1990

Thesis Advisor P.J. Marto
Co-Advisor S.B. Memory

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Heat transfer measurements have been made for filmwise condensation of steam on three families of horizontal integral finned copper tubes. The families differ from each other in their tube root diameter (12.7mm, 19.05mm, 25.00mm). The tubes making up each family differ from each other only in the fin spacing. Similar measurements have been carried out on three smooth horizontal copper tubes of outside diameters equal to the root diameters of each family, allowing the heat transfer enhancements due to the fins to be measured directly. Results carried out under vacuum and atmospheric conditions indicate that there is a optimum fin spacing which is independent of tube root diameter and operating pressure. This optimum fin spacing is 1.5mm.

Heat transfer measurements were carried out on all tubes with and without the use of a spiral insert (used to enhance the internal heat transfer). It was found that with the current processing technique used, the heat transfer enhancement for a finned tube (which is based on the outside heat transfer coefficient) varies depending on whether or not an insert is used, the enhancement being lower when no insert is used. However, it was found that when testing a smooth tube there was no difference when an insert was or was not used. There is a need to develop a more accurate correlation for the inside heat-transfer coefficient.

Further tests have been repeated using a finned tube geometrically similar to one being tested at the University of London. Discrepancies that existed between the two sets of data have been eliminated.

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Further Developments of Filmwise Condensation of Steam on Horizontal Integral Finned Tubes

by

Mark Brady Guttendorf
Lieutenant, United States Navy
B.S., Pennsylvania State University, 1982

Submitted in partial fulfillment of the
requirements for the degrees of

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and
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ABSTRACT

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Further tests have been repeated using a finned tube geometrically similar to one being tested at the University of London. Discrepancies that existed between the two sets of data have been eliminated.

endorf, m.

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NOMENCLATURE

A	surface area for heat transfer consistent with U (m^2)
A_c	cross sectional area of test tube (m^2)
A_f	surface area of fin (m^2)
A_i	effective inside surface area (m^2)
A_o	effective outside surface area (m^2)
A_r	surface area of smooth tube (m^2)
C_i	Sieder – Tate leading coefficient
c_p	specific heat at constant pressure ($J/kg\ K$)
D_f	fin diameter (m)
D_r	root diameter (m)
e	fin height (m)
g	gravitational constant ($9.81 m/s^2$)
h	condensing coefficient based on $A = \pi D_f L$ (W/m^2K)
h_b	condensing coefficient for flooded portion (W/m^2K)

h_{BK}	Beatty – Katz outside heat transfer coefficient (W/m^2K)
h^*_{BK}	modified Beatty – Katz condensing coefficient (W/m^2K)
h_f	condensing coefficient of fins (W/m^2K)
h_{fg}	specific enthalpy of vaporization (J/kg)
h_h	condensing coefficient for smooth horizontal tube (W/m^2K)
h_i	inside heat transfer coefficient (W/m^2K)
h_o	outside heat transfer coefficient (W/m^2K)
k_c	thermal conductivity of cooling water (W/mK)
k_l	thermal conductivity of condensate (W/mK)
k_m	thermal conductivity of metal tube (W/mK)
L	length of exposed tube (m)
$LMTD$	log mean temperature difference (K)
L_1	length of inlet portion of tube (m)
L_2	length of outlet portion of tube (m)
$\dot{m}$	mass flow rate (kg/s)

Pr	*Prandtl number*
Q	*heat transfer rate* (W)
q	*heat flux* (W/m^2)
Re	*Reynolds number*
R_i	*inside resistance* (K/W)
R_o	*outside resistance* (K/W)
R_w	*wall resistance* (m^2K/W)
s	*interfin spacing for rectangular fins* (m)
s_b	*interfin spacing at base* (m)
t	*fin thickness for rectangular fin* (m)
t_b	*fin thickness at base* (m)
t_t	*fin thickness at tip* (m)
T_{sat}	*vapor saturation temperature* (K)
T_1	*cooling water inlet temperature* (K)
T_2	*cooling water outlet temperature* (K)

U	*overall heat transfer coefficient* (W/m^2K)
U_∞	*vapor velocity* (m/s)
V	*cooling water velocity* (m/s)
α	*dimensionless coefficient*
β	*fin tip half angle (degrees)*
$\varepsilon_{\Delta T}$	*enhancement ratio based on constant* ΔT
ε_q	*enhancement ratio based on constant* q
Ψ	*condensate retention angle (degrees)*
μ_c	*dynamic viscosity of cooling water at bulk temperature* ($N\ s/m^2$)
μ_l	*dynamic viscosity of condensate* ($N\ s/m^2$)
μ_w	*dynamic viscosity of cooling water at inner wall temperature* ($N\ s/m^2$)
ρ_c	*test tube cooling water density* (kg/m^3)
ρ_l	*condensate density* (kg/m^3)
η	*surface efficiency*
η_f	*fin efficiency*

η_1 *fin efficiency for inlet portion of tube*

η_2 *fin efficiency for outlet portion of tube*

σ *surface tension* (N/m)

ΔT_{vs} *temperature drop across condensate film* (K)

ΔT *cooling water temperature rise* (K)

ΔT_f *average temperature difference across condensate film* (K)

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I. INTRODUCTION

A. BACKGROUND

There is no foreseeable limit to the new technologies that are being developed for and implemented in today's naval vessels. Weapons systems and their associated computers and sensors are more powerful than ever. As these new technologies find their way into our naval vessels, they bring with them larger energy demands, larger cooling demands, and in many cases, increased space and weight requirements. As energy costs, concerns, and requirements grow, the navy is faced with the task of becoming more efficient. Modern marine propulsion plants must be designed to provide the maximum power with the smallest, lightest and most cost effective equipment. Decreasing the size and weight of main and auxiliary heat exchangers is one means by which this may be accomplished. The Naval Postgraduate School (NPS) along with the David Taylor Research Center and support from the National Science Foundation is currently involved in research to reduce the size and weight of condensers.

The effectiveness of condensers is limited by the thermal resistances of the coolant side, the vapor side and the tube wall. Reducing any of these resistances will result in a better overall heat transfer coefficient. One way to reduce the thermal resistances on the coolant and vapor sides is through tube enhancement. Coolant side enhancement is achieved by using turbulence promoters such as ribs or inserts. Vapor side enhancement can be achieved by using fins of various shapes and sizes. This thesis studies vapor side enhancement, specifically low integral fin condenser tubes.

B. CONDENSATION

Condensation may occur in one of two possible ways, filmwise or dropwise. With filmwise condensation, the condensate film covers the entire condensing surface and, under the action of gravity, the film flows continuously from the surface. With dropwise condensation, the condensate forms discrete drops on the surface which grow, coalesce and, when big enough, drain from the surface under the action of gravity. The surface will be covered with drops, ranging from a few micrometers in diameter to larger ones visible to the naked eye. Regardless of whether it is in the form of a film or droplets, the condensate provides a resistance between the vapor and the surface. Because this resistance increases with condensate thickness, which increases in the flow direction, it is desirable to use short vertical surfaces or horizontal cylinders in situations involving film ndensation. In terms of maintaining high condensation and heat transfer rates, droplet formation is superior to that of film formation. In dropwise condensation most of the heat transfer is through drops less than $100\mu m$ in diameter, and transfer rates that are more than an order of magnitude larger than those associated with film condensation may be achieved. Although it would be desirable to achieve dropwise condensation because of the higher convection coefficients, it is difficult to maintain it over long periods. For this reason, condenser design calculations are based on the assumption of film condensation, often yielding conservative results. [Ref. 1]

C. HEAT EXCHANGER HEAT TRANSFER ANALYSIS

The basic equation used for the transfer of heat between a hot and cold fluid in heat exchanger design is:

$$Q = UA(LMTD) \tag{1.1}$$

where:

$Q = Heat\ transfer\ rate\ across\ the\ surfaces$

$U = Overall\ heat\ transfer\ coefficient$

$A = Surface\ area\ for\ heat\ transfer\ consistent\ with\ U$

$LMTD = Log\ mean\ temperature\ difference\ (between\ the\ vapor\ and\ the\ coolant)$

This gives a relationship between the temperature difference and the heat transfer rate in the heat exchanger. In a condenser with coolant flowing inside a condenser tube and vapor condensing on the outer tube surface, resistances limit the overall heat transfer coefficient (U) and subsequently the heat transfer rate. Because of the low thermal conductivity of most liquids in a bulk flow, the coolant side thermal resistance is usually dominant. Methods of decreasing the coolant side resistance include the use of turbulence promoters (such as twisted inserts) or internal ribbing. However, the increased internal pressure drop associated with these methods require additional pumping power; also the likelihood of fouling increases so there is a trade-off. The tube wall thermal resistance is purely conductive and is constant for a given material. An optimal balance between high conductivity, low corrosivity and light weight are sought when choosing a material. The vapor side thermal resistance is due to the condensate film which forms on the outer tube surface. Decreasing the vapor side thermal resistance can be accomplished through increasing the outside surface area by the use of fins or by using drainage strips or (for dropwise condensation), the use of dropwise promoting coatings.

The log mean temperature difference (LMTD), which gives an effective temperature difference between the vapor and the coolant, is a function of the coolant inlet and outlet temperatures and the vapor saturation temperature.

$$LMTD = \frac{(T_2 - T_1)}{\ln\left[\dfrac{T_{sat} - T_1}{T_{sat} - T_2}\right]} \tag{1.2}$$

where:

$T_1 = Coolant\ inlet\ temperature$

$T_2 = Coolant\ outlet\ temperature$

$T_{sat} = Vapor/Condensate\ saturation\ temperature$

The overall heat transfer coefficient (U) is inversely proportional to resistance to heat transfer. The area (A) consistent with this coefficient is the outside area of the tube. Normal convention dictates this. Therefore, increasing the outside surface area should result in a higher heat transfer rate. However, it turns out that increasing the outside surface area by the use of fins gives a higher heat transfer enhancement than would be expected from the area increase alone. Wanniarachchi et al. [Ref. 2] and Yau et al. [Ref. 3] observed that the increase in heat transfer is due not only to the area increase but also to thinning of the condensate film on the fin tips and flanks due to surface tension effects. High surface tension fluids such as steam, once thought to be unacceptable for use with finned tubes because of the large amount of interfin flooding which occurs, were included in this observation.

D. CONDENSATION RESEARCH AT THE NAVAL POSTGRADUATE SCHOOL

The current program at NPS to study the effects of enhanced surfaces in condensation began in 1982. Van Petten [Ref. 4] summarizes the work done up until December 1988. The program of work was designed as a systematic study to determine the effects of varying fin parameters such as fin spacing, shape and height and vapor/liquid environments on condensation heat transfer enhancement. Van Petten studied the effects of varying tube diameters (fin root diameters of 12.7, 19.05, and 25.0 mm) with three different test fluids (steam, R-113, and ethylene glycol). The fluids were chosen because they were inexpensive, readily available, had well documented fluid properties and a wide range of surface tensions. He found that the optimum fin spacings (ie. the fin spacings which gave the largest increase in heat transfer when area effects have been taken into account) were 0.5, 1.0, and 1.5 mm for R-113, ethylene glycol and steam respectively. He also found that the effect of root diameter on the vapor side coefficient was small and that two or more competing mechanisms may exist as root diameter increases. As tube root diameter increases, the condensate retention angle decreases resulting in a larger portion of the tube being unflooded. This should lead to an increase in enhancement. However, when tube diameter increases, the condensate must flow along a longer path from the top to the bottom of the tube. This longer path yields a larger than average film thickness in the unflooded portion of the tube. This degrades the performance in the unflooded portion of larger diameter tubes. Van Petten also compared his results for a particular tube with those of a similar tube which was being used in a concurrent research project at Queen Mary College (University of London). He found that his results compared very well for R-113 but not for steam. The steam comparison exhibited a large discrepancy, the QMC data giving much lower enhancements. All condensation tests done at NPS using steam as the working fluid are done with a spiral insert in the condenser test tube. The reasons for using an insert when steam is the working fluid are that inserts can reduce the thermal resistance on the inside of the tube which, for steam, may be as much as 50 to 60 percent of the total resistance when no insert is used. Inserts also reduce circumferential wall temperature variations and thermal entrance effects by inducing quicker turbulent boundary layer growth.

Up to this point, the effect of vapor velocity had not been studied. In December 1988, Hopkins [Ref. 5] looked at the effect of vapor velocity (up to 31 m/s) on filmwise condensation heat transfer enhancement. Flook [Ref. 6], a previous NPS student (Dec 84), also tested for vapor velocity effects but achieved vapor velocities only up to 8 m/s. Hopkins tested one smooth tube and three finned tubes using steam and R-113 as the working fluids. He found that the smooth tube experienced the largest percent increase in outside heat transfer enhancement with increase in vapor velocity. Furthermore, he also found that as vapor velocity increased, finned tube enhancement dropped off and approached that of smooth tubes at similar velocities. Hopkins noted that for the two fluids tested, finned tube performance (ie. enhancement over a similar smooth tube) showed opposite trends. With R-113 as the working fluid, tube performance increased as fin spacing increased. With steam as the working fluid, tube performance decreased with increased fin spacing. The exact reason for this was unknown.

In December 1989, Coumes [Ref. 7], in an attempt to resolve the discrepancy between NPS and QMC which arose during Van Petten's work, obtained a tube from

QMC and modified it for testing in the NPS apparatus. The main differences between the QMC tube and the NPS tube to which it was being compared were that the QMC tube had a shorter condensing length and a groove cut lengthwise across the fins for a drainage strip. Also, the machined quality of the tubes differed. The fin thickness for both tubes was supposed to be .5 mm. However, close inspection of the machined surfaces revealed that the fins on the QMC tube had thicknesses which ranged from .38 to .71 mm while the NPS tube had fin thickness which ranged from only .48 to .51 mm. Coumes only tested with steam and his results again showed poor comparisons. It should be noted that the QMC tube which Coumes refers to and the QMC tube which Van Petten refers to are different. The "QMC tube" used in the work of Coumes is the tube he obtained from London. Van Petten's "QMC tube" is one he had manufactured to enable direct comparison with QMC data. Coumes refers to this tube as the QMCNPS tube. Here they will be referred to as tube F086 (QMCNPS) and tube F087 (QMC London). Coumes also tested the small diameter tube family with steam as the working fluid in order to verify some of Van Petten's data. With the small tube family, Van Petten's results showed a drop in heat transfer enhancement for a fin spacing of 1.5 mm (the same spacing which showed maximum enhancements for the medium and large tubes with steam). Coumes results showed the same dip at 1.5 mm. Coumes also began modifications to the apparatus to study the effects of condensate inundation. He was unable to obtain any heat transfer data due to system integrity problems (ie. he was unable to get the system vacuum tight) but he was able to observe condensate flow patterns for various condensate flow rates.

E. OBJECTIVES

The main objectives of this thesis were:

1. Collect steam condensation data on single horizontal finned tubes of differing diameters for comparison with previously obtained NPS results.
2. Manufacture a large diameter smooth tube to be tested in addition to small and medium diameter smooth tubes previously tested to compare and determine the effect of tube diameter on smooth tube results.
3. Collect steam condensation data on single horizontal tubes of differing diameters with and without the spiral insert to determine the effects of the insert on the data reduction scheme.
4. Have a new small diameter tube family manufactured, in particular tubes with fin spacings of 1.25 and 1.75 mm, to verify the dip in the heat transfer enhancement at a fin spacing of 1.5 mm.

II. LITERATURE SURVEY

A. INTRODUCTION

When vapor condenses in the filmwise mode on a smooth horizontal tube, a thin, continuous layer of condensate forms on the tube. As the condensate flows down around the perimeter of the tube, the condensate film thickens. The condensate film provides a resistance to heat transfer which increases as the film thickness increases. In order to enhance the heat-transfer of a tube, this condensate film and its associated resistance must be reduced. Some methods used to thin the condensate film involve the use of finned surfaces, wire wrapped tubes and porous drainage strips. The focus of this investigation is the continuation of ongoing research at the Naval Postgraduate School to study the effects of finned surfaces on heat-transfer enhancement of horizontal condenser tubes.

For many years, finned tubes were considered unsuitable for use with high surface tension fluids (eg. water) because of the large amount of liquid retention or interfin flooding on the bottom portion of the tubes. This thick film on the bottom portion of the tube was thought to negate the effects due to thinning of the film on the upper portion of the tube. However, recent work by Wanniarachchi et al. [Ref. 8] and Yau et al. [Ref. 3] has shown that there is considerable enhancements even for fully flooded tubes. Apparently heat-transfer at the fin tips is still effective. It is essential, therefore, to understand the complex physical phenomena that occur in this two-phase heat-transfer situation. Marto [Ref. 9] provides an extensive review and development of film condensation on horizontal finned tubes.

B. CONDENSATE RETENTION

When a horizontal finned tube comes in contact with a highly wetting liquid, surface tension forces cause the liquid to be retained between fins on the bottom portion of the tube. The condensate retention angle (Ψ) has been defined as the angle measured from the bottom of the tube to a point around the tube circumference where the condensate film between fins just fills the entire interfin space. This angle, shown in Figure 1, is dependent on the fluid properties and the fin geometry.

In 1946, the first measurements of condensate retention were made by Katz et al. [Ref. 10]. These measurements were made under static conditions (ie. no condensation taking place) using various fluids and fin densities. It was shown that as much as 100

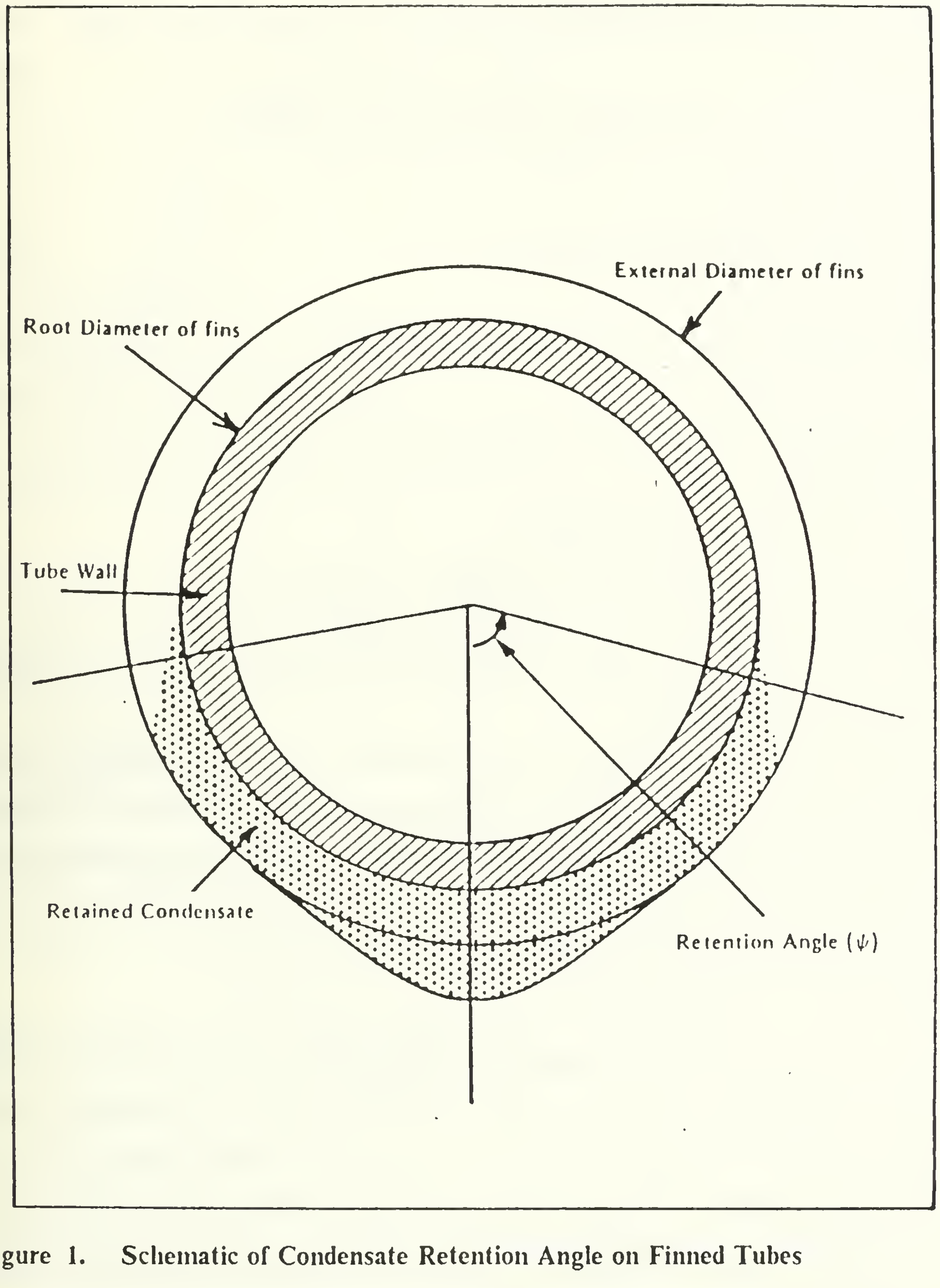

Figure 1. Schematic of Condensate Retention Angle on Finned Tubes

percent of the tube surface could be flooded with retained condensate, depending mainly on the ratio of surface tension to liquid density and on the fin spacing. Equation (2.1) shows the relationship developed by Katz et al.

$$\frac{\Psi}{\sin\Psi} = \frac{\sigma}{\rho_l g}\left[\frac{4D_f - 2D_r - 2s}{\frac{\pi}{4}\left(D_f^2 - D_r^2\right)s}\right]\left(\frac{180}{980}\right) \tag{2.1}$$

where

Ψ = *condensate retention angle (degrees)*

σ = *surface tension*

g = *gravitational constant*

ρ_l = *condensate density*

D_f = *fin diameter*

D_r = *root diameter*

s = *interfin spacing for rectangular fins*

This equation shows that increasing the ratio between the surface tension and the condensate density will lead to an increase in condensate retention angle. Also, for constant fin height and fin spacing, an increase in root diameter will lead to a decrease in condensate retention angle.

In 1981, Rudy and Webb [Ref. 11] were the first to measure condensate retention angles under both static and dynamic (condensation occurring) conditions. In addition to confirming the Katz et al. conclusions, they also concluded that the condensate retention angle did not differ significantly under static and dynamic conditions. Later, in 1983, Rudy and Webb [Ref. 12] developed the following equation to predict the condensate retention angle for finned tubes of different geometries:

$$\Psi = \cos^{-1}\left[1 - \frac{2\sigma(2e - t)}{D_f \rho_l g e s}\right] \tag{2.2}$$

where

e = fin height and

t = fin thickness for a rectangular fin

Rudy and Webb found that Equation (2.2) predicted the condensate retention angle to within 10 percent.

In 1983, Honda et al. [Ref. 13] confirmed, from a photographic study, the conclusion of Rudy and Webb that static and dynamic retention angles were approximately the same. Honda et al. developed the following expression for the condensate retention angle:

$$\Psi = \cos^{-1}\left[1 - \frac{4\sigma\cos\beta}{D_f\rho_l g s}\right] \tag{2.3}$$

where

$\beta =$ *fin − tip half angle*

They also showed that by attaching a porous drainage strip, the condensate retention angle could be significantly reduced.

In 1985, Rudy and Webb [Ref. 14] expanded their 1983 model to account for fins of trapezoidal shapes (see Figure 2). They developed the following expression:

$$\Psi = \cos^{-1}\left[1 - \frac{2\sigma(t_t + 2e - t_b)}{D_f\rho_l g(t_t e - s_b e - e t_b)}\right] \tag{2.4}$$

where

$t_t =$ *fin thickness at tip*

$t_b =$ *fin thickness at base*

$s_b =$ *interfin spacing at base*

For a rectangular shaped fin (ie. when $t_t = t_b$), Equation (2.4) reduces to

$$\Psi = \cos^{-1}\left[1 - \frac{4\sigma}{D_f\rho_f g s}\right] \tag{2.5}$$

which is identical to Equation (2.3) of Honda when $\beta = 0$ degrees.

In 1987, Masuda and Rose [Ref. 15], by observing static liquid retention on finned tubes, discovered that condensate was retained on the upper portion (previously referred to as the unflooded portion) of the tube as well as the bottom (flooded) portion of the tube. On the upper portion of the tube, the retained condensate forms a small liquid wedge between the flanks of the fins and the tube surface in the interfin space. This is shown schematically in Figure 3(a). Figure 3 also shows four different flooding conditions based on the profile of the liquid wedge. Masuda and Rose developed four separate expressions , one for each of the flooding conditions. Condition (3) was considered

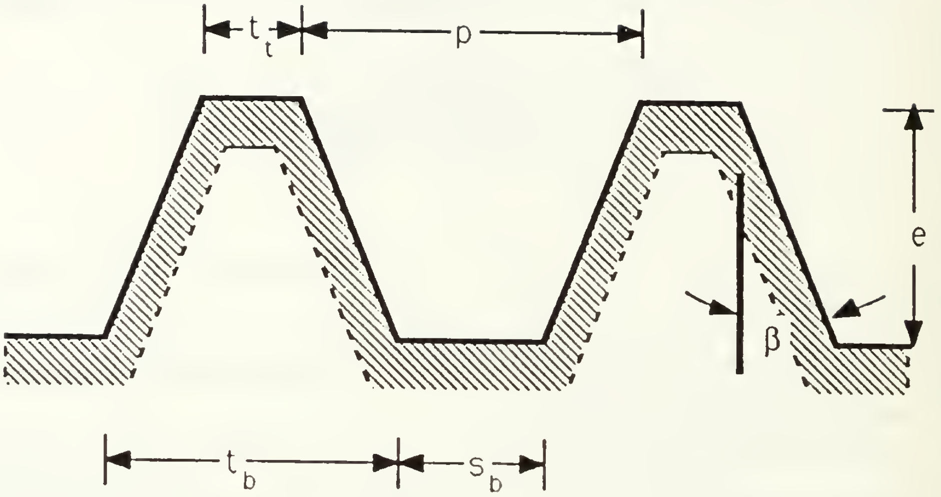

Figure 2. Trapezoidal Fin Used by Rudy and Webb

to be the fully flooded condition, and in this situation, their expression reduces to Equation (2.5) for rectangular shaped fins.

Honda et al. [Ref. 16], in 1987, developed two equations for the prediction of the condensate retention angle. One expression was used when the fin spacing was twice the fin height and the other when fin spacing was less than twice the fin height. The latter case, for rectangular finned tubes, reduces to Equation (2.5).

C. HEAT TRANSFER

In 1948, Beatty and Katz [Ref. 17] performed experiments condensing various fluids on single horizontal finned tubes to obtain the vapor side heat-transfer coefficient. Their model, which neglected surface tension completely, used the Nusselt analysis [Ref. 18] for condensation on a horizontal tube and condensation on a vertical surface. By considering the finned tube to be a combination of the two parts, a horizontal smooth tube with vertical fins, they arrived at the following expression for the average heat-transfer coefficient:

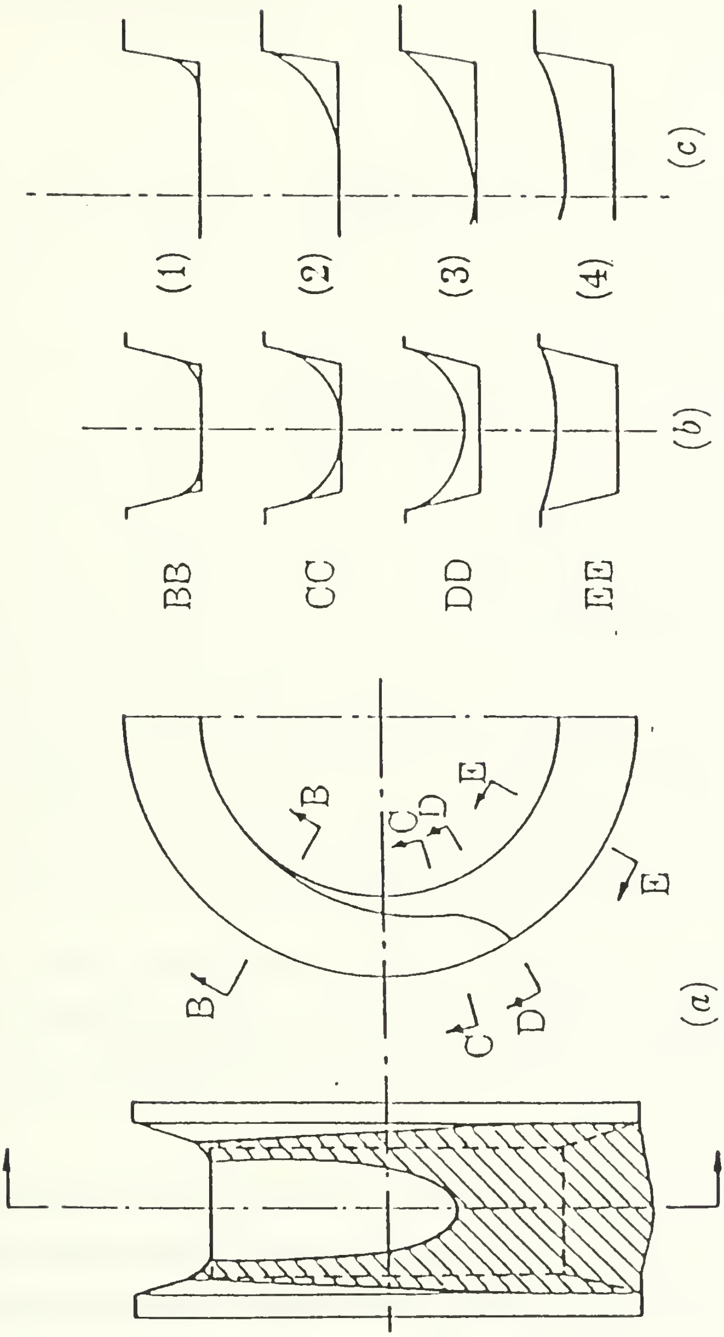

Figure 3. Flooding Conditions Proposed by Masuda and Rose

$$h_{BK} = 0.689 F_{BK}^{0.25} \left[\frac{A_r}{A_o} \left(\frac{1}{D_r} \right)^{0.25} + 1.3 \eta_f \frac{A_f}{A_o} \left(\frac{1}{L_e} \right)^{0.25} \right] \tag{2.6}$$

where

$$F_{BK} = \frac{k_l^3 \rho_l g h_{fg}}{\mu_l \Delta T_{vs}} \tag{2.7}$$

and

$$L_e = \pi \left[\frac{D_f^2 - D_r^2}{4 D_f} \right] \tag{2.8}$$

h_{fg} = *specific enthalpy of vaporization*

k_l = *thermal conductivity of condensate*

μ_l = *dynamic viscosity of condensate*

η_f = *fin efficiency*

ΔT_{vs} = *temperature drop across the condensate film*

A_r = *tube surface area between fins*

A_f = *surface area of fin (flank and tip)*

A_o = *total effective external surface area,* $A_o = A_r + \eta_f A_f$

This was the first analytical model to predict the condensing heat-transfer coefficient on a horizontal finned tube. The empirically determined leading coefficient (0.689) is only five percent less than the theoretically derived constant (0.728) using the Nusselt analysis for a smooth tube. Notice that Equation (2.6) shows that the heat-transfer coefficient decreases with increasing tube diameter.

In their experiments, Beatty and Katz only tested tubes with low fin densities and fluids with low surface tensions. Rudy and Webb [Ref. 11] found that the Beatty and Katz model overpredicted the results for fluids with a higher surface tension to condensate density ratio. They attempted to use the Beatty and Katz equation only for the unflooded portion of the tube (assuming that the heat-transfer in the flooded portion was negligible).

$$h_{BK}^{\times} = \left(\frac{180 - \Psi}{180} \right) h_{BK} \tag{2.9}$$

where

h^*_{BK} = *Modified Beatty and Katz Equation*

This equation resulted in underprediction of the experimental results by up to fifty percent.

Owen et al. [Ref. 19] concluded that the Rudy and Webb model underpredicted the results because of the assumption of no heat transfer in the flooded region. Owen et al., therefore, allowed for one-dimensional conduction through the condensate film in the flooded region but only obtained slightly improved results compared to Rudy and Webb.

It became apparent that condensation on a finned tube was a complex phenomena with a number of controlling parameters not considered in previous models. Among these are three-dimensional condensate flow, surface tension forces, wall conduction effects, condensate film thickness variations and vapor velocities [Ref. 20]. Gregorig [Ref. 21] in 1954 proved that, when condensation occurs on a vertical fluted surface, surface tension also produces pressure gradients that thin the condensate film around the flute tips and along the flute sides. But Marto [Ref. 9] points out that Karkhu and Borovkov [Ref. 22], in 1971, developed the first analysis which recognized the importance of surface tension on horizontal finned tubes.

In 1985, Webb et al. [Ref. 23] proposed a refined model to the Owen et al model. It included surface tension drainage on the fin flanks, gravity drainage on the interfin tube surface and heat transfer in the flooded region. Equation (2.10) is their refined model.

$$h\eta = \left(\frac{180 - \Psi}{180} \right) \left[h_h \frac{A_r}{A} + h_f \eta_f \frac{A_f}{A} \right] + \frac{\Psi}{180} h_b \tag{2.10}$$

where

h = *condensing heat – transfer coefficient based on* $A = \pi D_f L$

h_f = *heat – transfer coefficient based on the fin surface*

h_h = *heat – transfer coefficient based on the smooth horizontal tube*

h_b = *heat – transfer coefficient based on the flooded region*

L = *length of the tube*

η = *surface efficiency* $= \left[1 - (1 - \eta_f) \dfrac{A_r}{A_r + A_f} \right]$

A_r = *tube surface area between fins*

A_f = *surface area of fins (flank and tip)*

This model divided the finned tube into two regions, the flooded region and the unflooded region. The unflooded region was further subdivided into two more regions, the finned region and the interfin smooth tube region. Each of these regions had an associated condensing heat-transfer coefficient. An area weighted average of these three condensing heat transfer coefficients (h_f, h_h, h_b) resulted in the average outside heat transfer coefficient. For the condensing coefficient for the fin (h_f), the surface tension controlled heat-transfer coefficient proposed by Adamek [Ref. 24] was used. For the horizontal smooth heat-transfer coefficient (h_h), a modified Nusselt expression, which accounted for additional condensate from the fin flanks, was used. For the flooded region, the heat-transfer coefficient (h_b) was determined by use of a two-dimensional conduction approach for the fin-liquid combination. With this model, Webb et al. found that experimental and theoretical results agreed to within twenty percent.

In 1987, Honda et al. [Ref. 25] introduced the most complete, detailed model to date. This model includes the effect of variable wall temperature which enables the problem to be treated as a composite problem involving vapor to coolant heat-transfer through a finned tube wall. As discussed by Marto [Ref. 9], the Honda model appears to give the most accurate predictions of the experimental results , with agreement to within 20 percent, over the entire range of fin spacings tested.

III. APPARATUS AND TUBES TESTED

A. SYSTEM OVERVIEW

The apparatus used for this research was essentially the same as used by Van Petten [Ref. 4] and Coumes [Ref. 7] with minor modifications. A schematic of the system is shown in Figure 4. It consisted of a boiler, glass piping, test section, auxiliary condenser and a purging system to remove non-condensing gases. Steam was generated in .3048m diameter pyrex glass boiler using ten 4kW 440V Watlow immersion heaters. After passing through a .3048m to .1524m reducing section, the steam flowed upward through a 2.44m long section of pyrex glass piping, around two simultaneous 90 degree bends and back down a 1.52m length of pyrex glass piping before entering the stainless steel test section. The condenser tube to be tested was mounted horizontally across the test section. A circular viewing port allowed visual observation of the condensing process. Figure 5 shows details of the test tube mounted in the test section. Steam which did not condense on the test tube passed into the auxiliary condenser located directly below the test section. The auxiliary condenser consisted of two concentrically wound copper coils inside pyrex glass piping.

Cooling water for the test tube was provided by two centrifugal pumps connected in series. Water to these pumps was provided from a sump tank which was filled with a continuous supply of tapwater. The cooling water flow rate to the test tube was controlled by a throttle valve at the inlet to the flowmeter. The water could be throttled to achieve coolant velocities of up to 4.4 m/s for the medium and large diameter test tubes (which have the same internal diameter) and 6.5 m/s for the small diameter test tubes.

Auxiliary cooling water was supplied by tapwater throttled at the inlet of another flowmeter. Throttling the flow of tapwater through the auxiliary condenser and thereby controlling the rate of condensation in the auxiliary condenser was the means used to control the internal pressure of the test apparatus.

To purge the system of all noncondensibles, a vacuum pump was connected to the apparatus below the test section. A schematic is shown in Figure 6. Air drawn by the pump left the auxiliary condenser via copper tubing and discharged to atmosphere via a copper coil located in the cooling water sump. This provided heat exchange and condensed any residual working fluid vapor before it reached the vacuum pump. The condensate collected in a plexiglass sump and was emptied via a drain valve at the con-

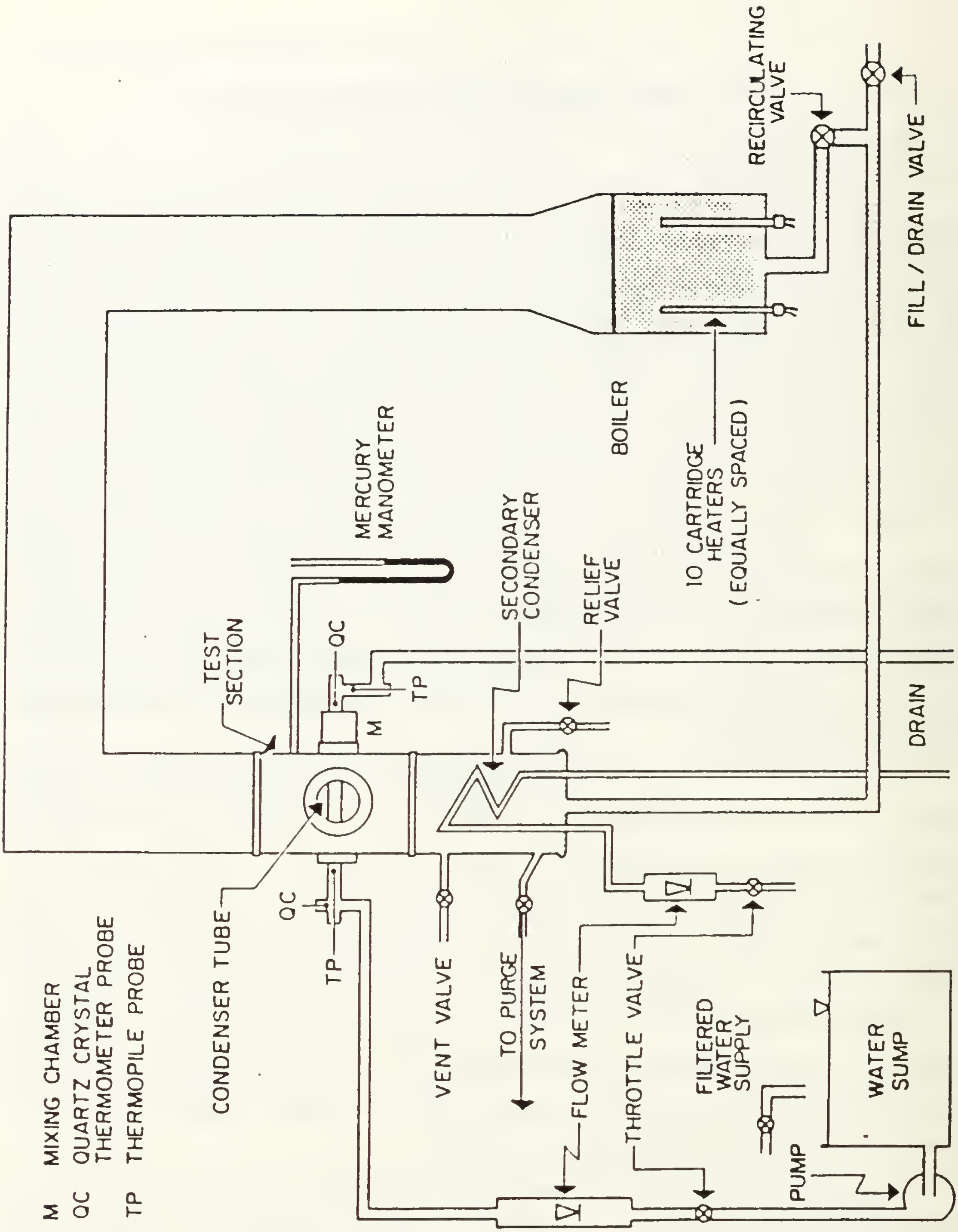

Figure 4. Schematic of Single Tube Test Apparatus

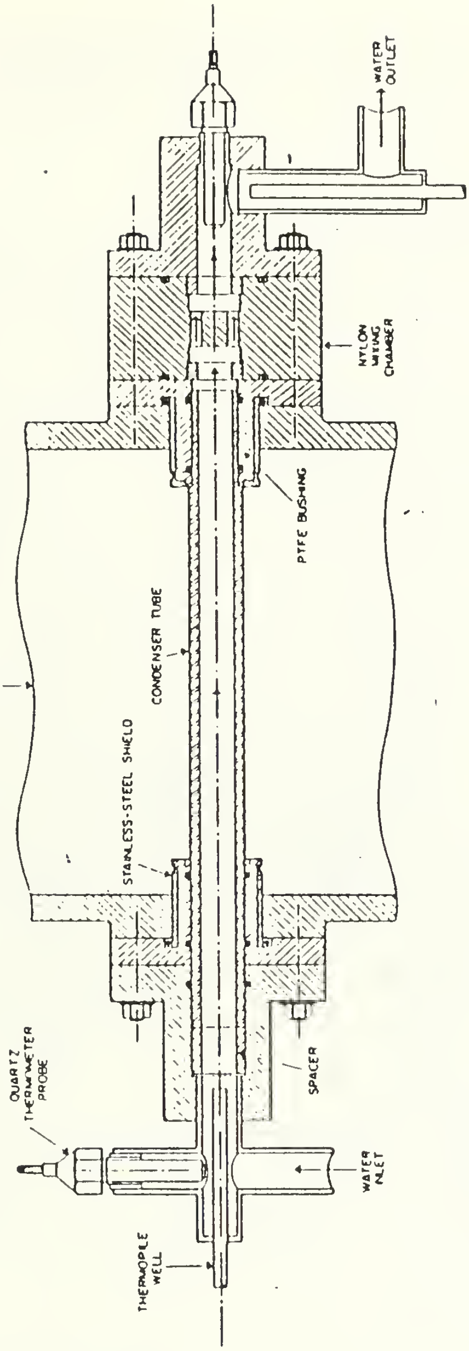

Figure 5. Schematic of Test Section Insert Removed

lusion of each run. The non-condensing gases were suctioned to the top of the container and drawn into the vacuum pump. Detailed descriptions of this apparatus are provided in Refs 4-7,26,27,33.

B. SYSTEM INSTRUMENTATION

The input power to the heaters was varied through a panel mounted potentiometer. A converter with an input voltage of 440V ac generated a signal which was fed into the data acquisition system in order to calculate the power input to the heaters. A detailed description of this converter function is given by Poole [Ref. 26].

A U-tube mercury-in-glass manometer graduated in millimeters was used to measure the internal pressure of the system. This was tapped into the test section, just above the test tube. An electrically well insulated copper-constantan thermocouple placed in a housing was also located just above the test tube to measure the vapor temperature. The temperature rise of the cooling water through the test section was measured by two Hewlett-Packard (HP) 2804A quartz crystal thermometers as well as by a 10 junction, series connected, copper-constantan thermopile. The temperatures were fed directly into the data acquisition system described below. Throughout the investigation, the cooling water temperature rise measured by the quartz thermometers and the thermopile agreed to within five percent. There were some fluctuations in the thermopile readings, believed to be caused by ambient frequency fluctuations. The data reduction program used the quartz thermometer measurements for all calculations because of the higher degree of accuracy. Calibration data for the quartz thermometers is given in Appendix A.

C. DATA ACQUISITION SYSTEM

An HP 3497A data acquisition system, as controlled by an HP 9826A computer was used to monitor system temperatures and the power input to the heaters. The data were immediately processed and stored on computer disks for later reduction and evaluation.

D. SYSTEM MODIFICATIONS

At the beginning of the current investigation, the test section was the same as that used by Hopkins and Coumes. This was a different test section than that used by Van Petten enabling Hopkins to conduct high velocity experiments and Coumes to study inundation effects. The essential differences between the old and new sections are (see Figures 7-10):

1. The condensation test tube inlet and outlet supports on the new test section are rectangular (as opposed to circular) enabling up to four separate horizontal tubes to be mounted in a vertical plane.

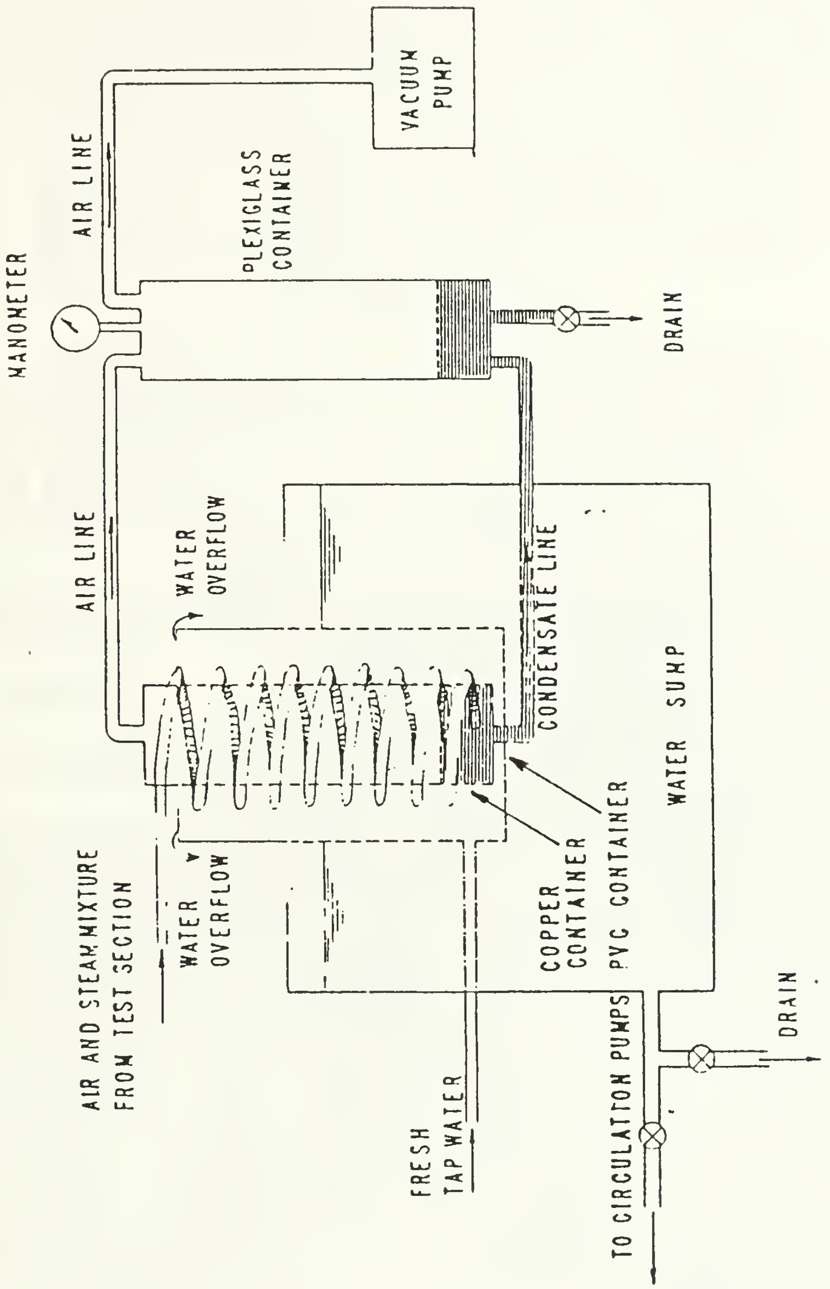

Figure 6. Schematic of Purging System and Cooling Water Sump

2. The viewing window on the new test section is rectangular (as opposed to circular) to give better visual observation of the multiple tube arrangement.
3. The pressure tap for the manometer and the thermocouple housing for the new test section are located below the test tube. One problem with this configuration was that condensate would drip directly onto the thermocouple housing causing some unknown fluctuation in the temperature readout.
4. The inlet and outlet cooling water attachments were changed on the new test section and a different mixing chamber was added to the outlet end.

Initial testing with the new test section (to check repeatability with previous single tube tests on the old test section) showed that dropwise condensation was occurring on the tube surface. The cause for this was unknown since the test tube had been chemically treated to prevent formation of dropwise condensation. This procedure is discussed more fully in a later chapter. It was suspected that the system may have been previously contaminated with a vacuum grease used in an attempt to achieve a vacuum tight system. The apparatus was cleaned several times by operating with a solution of Sparkleen (a commercial detergent used for cleaning laboratory glassware) and water at temperatures of 100 degrees C for approximately one hour. After allowing the system to cool, the soap and water solution was drained and the apparatus filled and operated with distilled water to rinse and steam clean the system. The steam cleaning procedure was performed at least twice after operating with the soap and water.

When tests were repeated, there were still small traces of dropwise condensation on the test tube. However, it was found that complete wetting of the tube could be achieved by rotating the tube slightly. Once good filmwise condensation was obtained (often after rigorous cleaning of the tubes), a review of the experimental data obtained with this new test section showed that there were differences when experiments were performed on the same tube in new test section and the old test section. The most likely explanations for the differences in results between the two sections were that first, on the inlet side of the new test section, the coolant hose fittings were attached directly to the tube via metal couplings thus giving rise to the possibility of conduction losses. In addition, the improved mixing chamber on the new test section was located further downstream from the outlet end of the tube (due to space limitation) and it was felt that this may not give a truly accurate value of the temperature at the exit. It was decided to place the old test section back in the apparatus. This would eliminate the possibilities of differences in results being due to differences in the test apparatus. The old test section would enable a direct comparison with other single tube, low velocity data under the same conditions.

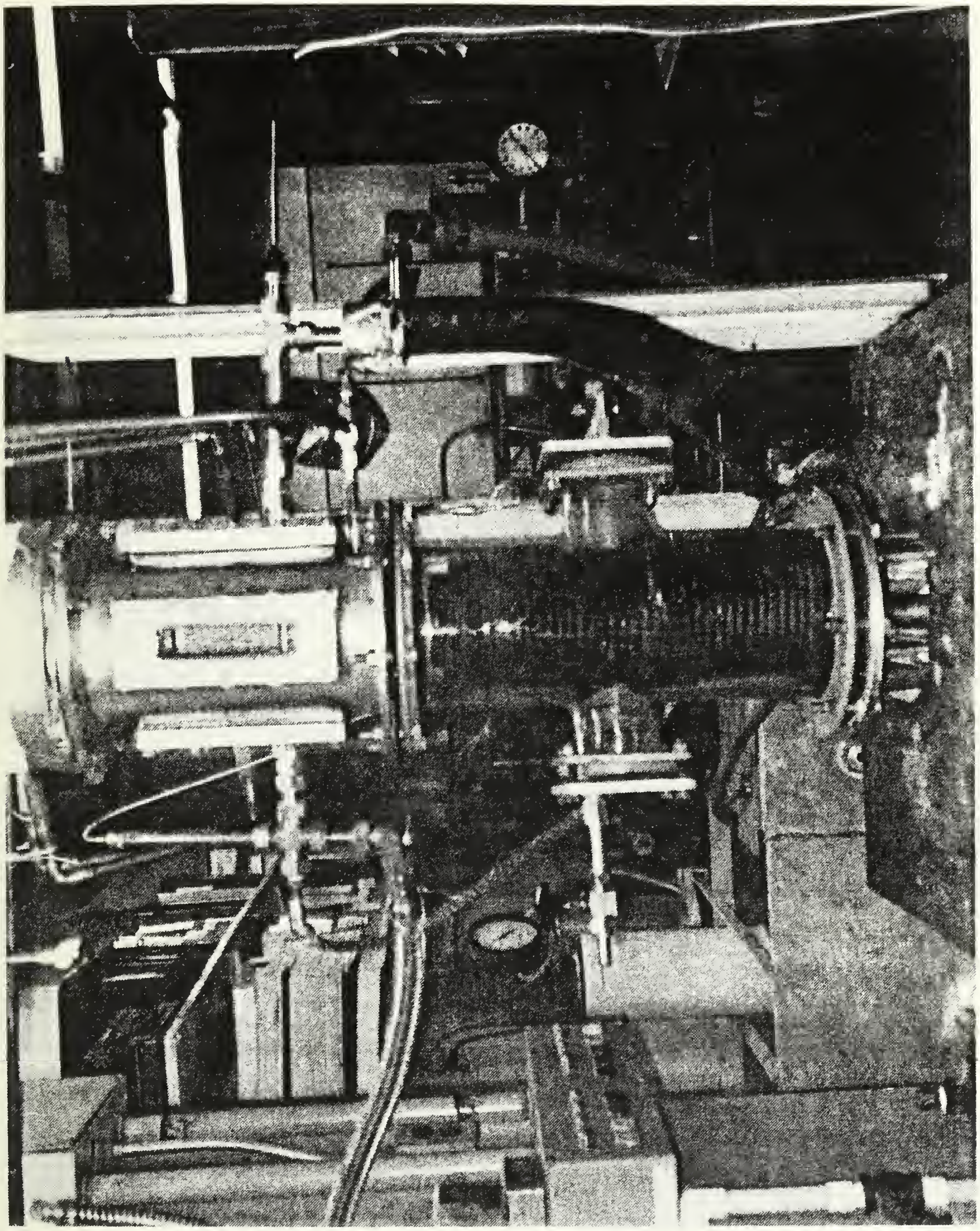

Figure 7. Photograph of New Test Section

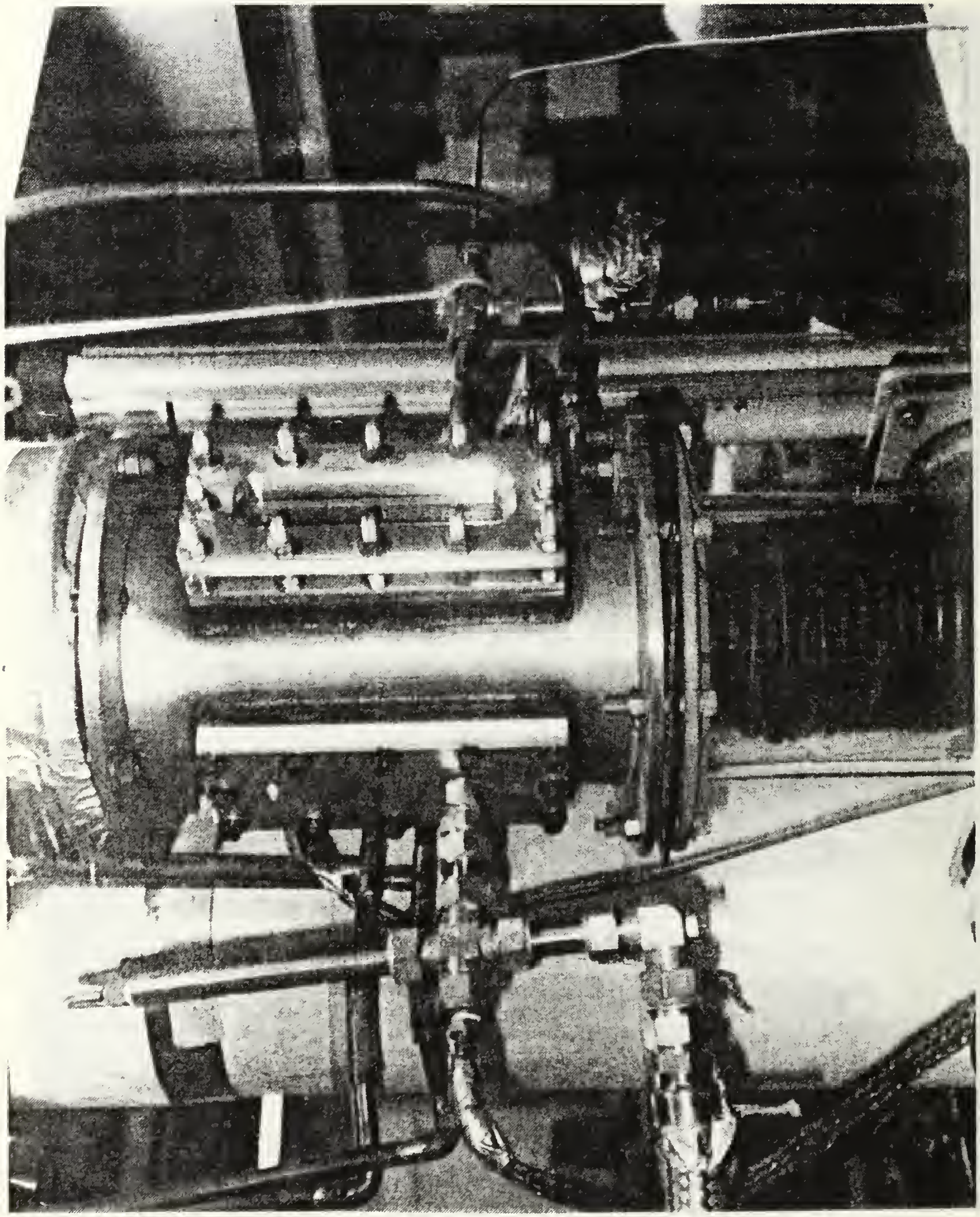

Figure 8. Photograph of New Test Section

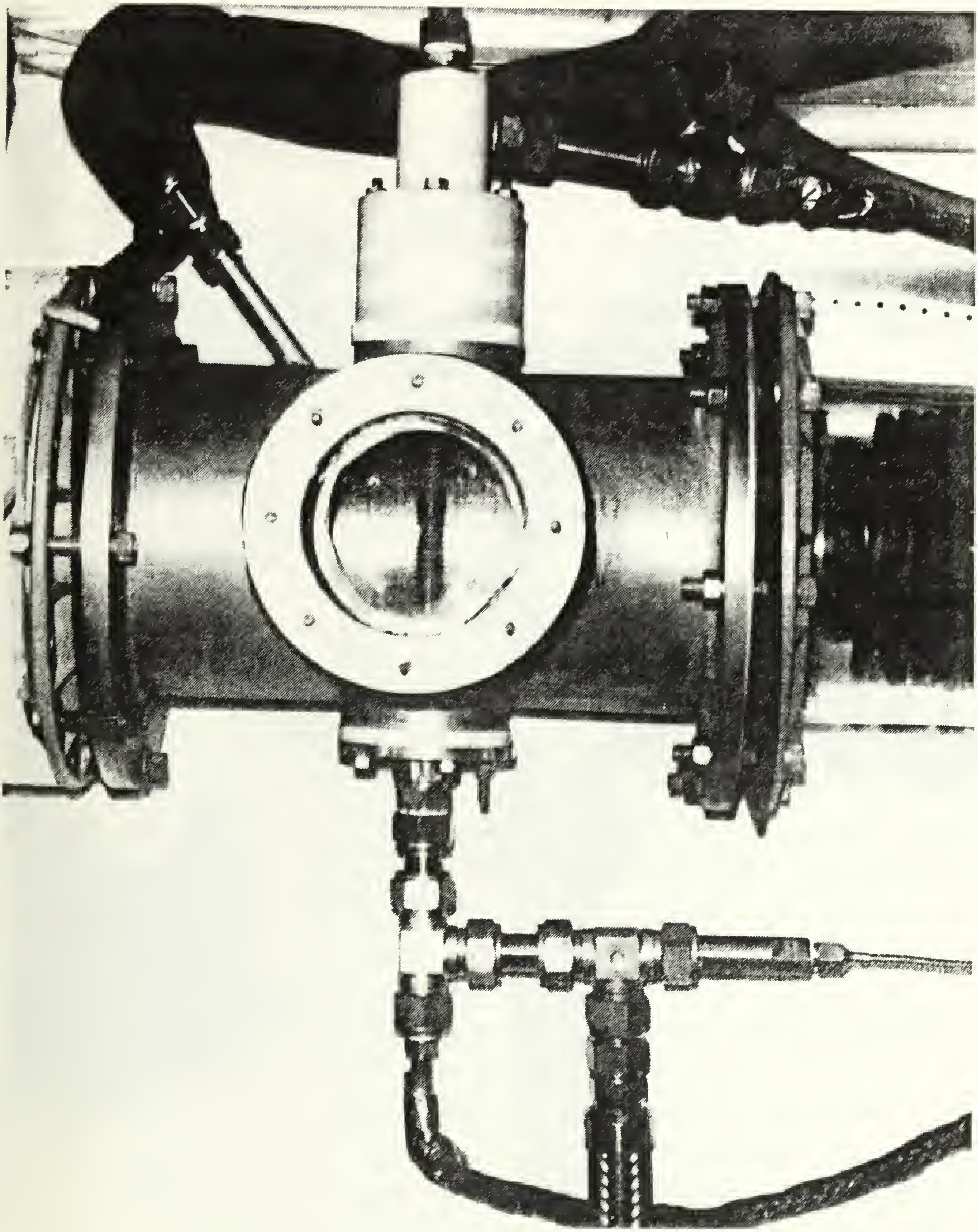

Figure 9. Photograph of Old Test Section with Modified Inlet

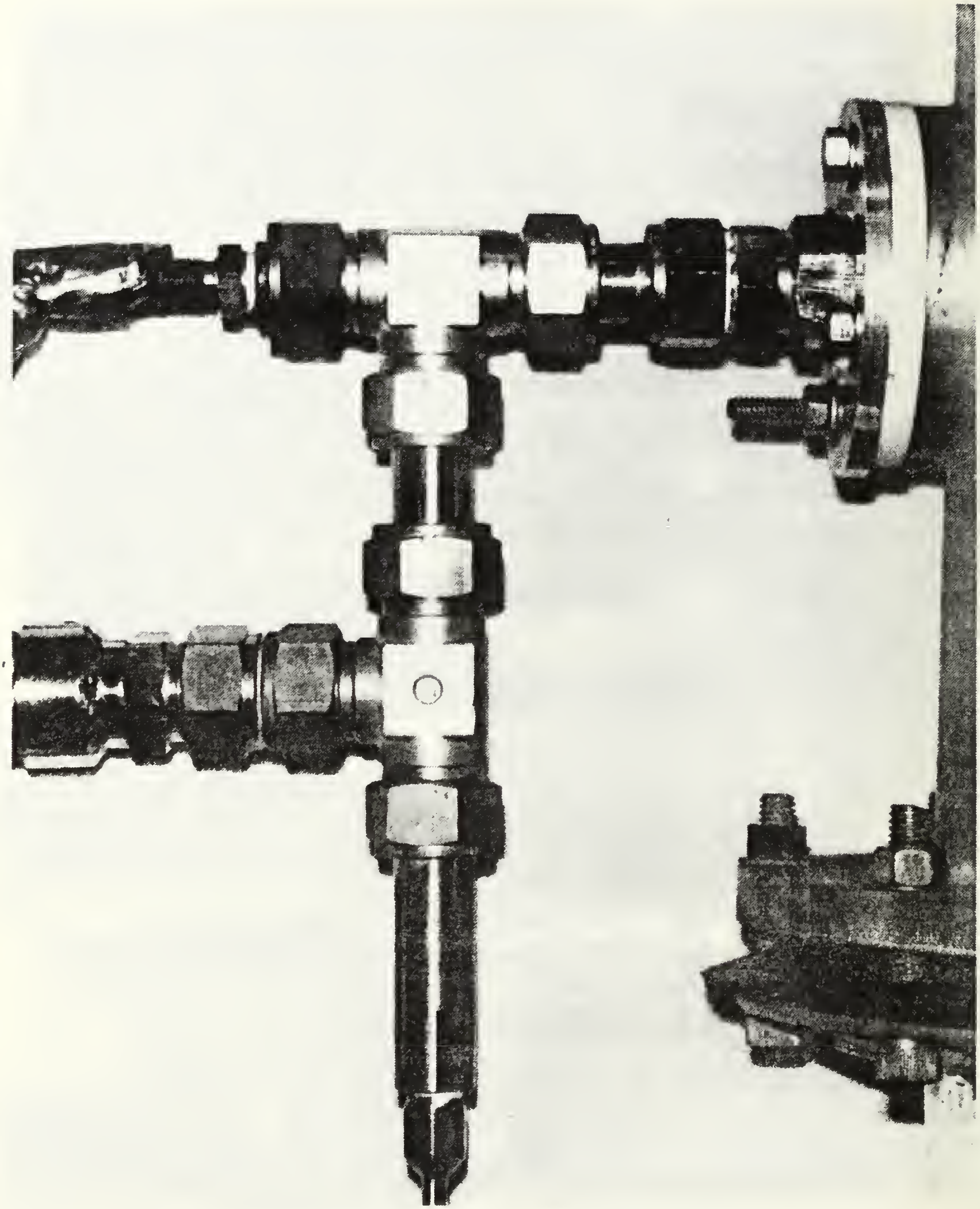

Figure 10. Photograph of Old Test Section with Modified Inlet

After installing the old section and ensuring vacuum tightness of the system (this procedure will be discussed in more detail later in this chapter), experiments continued. Partial dropwise condensation was still occurring. The old test section did not allow for the test tube to be turned manually so the inlet had to be modified slightly. Photographs of the original setup before this modification are shown in Figures 11 and 12. This enabled turning of the tube but it also introduced the same inlet end conduction losses which had been a concern with the new test section. However, being able to turn the tube and wet the entire tube surface got rid of the dropwise condensation. Experimental results showed good agreement with past results and it was felt that the conduction losses on the inlet end caused by this modification were negligible. Another small but significant modification at the inlet was changing the orientation of the quartz thermometer probe. In Figure 5 it can be seen that with the original setup, a flow stagnation point may occur at the tip of the quartz thermometer giving rise to inaccurate temperature measurements. The new setup allows for a free flow around the thermometer tip.

E. TUBES TESTED

Three smooth tubes and sixteen finned tubes were tested using steam as the working fluid (see Table 1). All tubes were manufactured from oxygen-free high conductivity copper. The three smooth tubes were of varying outside diameters: small (9.52 mm), medium (19.05 mm), and large (25.00 mm). A photograph of the three smooth tubes is shown in Figure 13. Each finned tube was manufactured such that the root diameter matched the outside diameter of one of the smooth tubes. Of the sixteen finned tubes tested, twelve belonged to the small tube 'family', two belonged to the medium tube 'family' and one belonged to the large 'family'. All of the finned tubes had rectangular shaped fins (height and thickness of each fin equal to 1.0 mm). Each 'family' was made up of a series of tubes with varying fin spacing. A photograph showing one finned tube from each family (small, medium and large) is shown in Figure 14. The small finned tube family was broken down into two groups: the old small finned tube group which was tested by Coumes [Ref. 7] and Van Petten [Ref. 4] and the new small finned tube group which was manufactured for this investigation. The old small finned tube group had fin spacings of .25, .50, 1.0, 1.5, 2.0, and 4.0 mm. The new small finned group had fin spacings of .25, .50, 1.0, 1.25, 1.5, and 1.75 mm. A photograph of the small tube family with one tube of each fin spacing is shown in Figure 15. The new small finned tube group was manufactured for two reasons. Firstly they would provide more detailed ex-

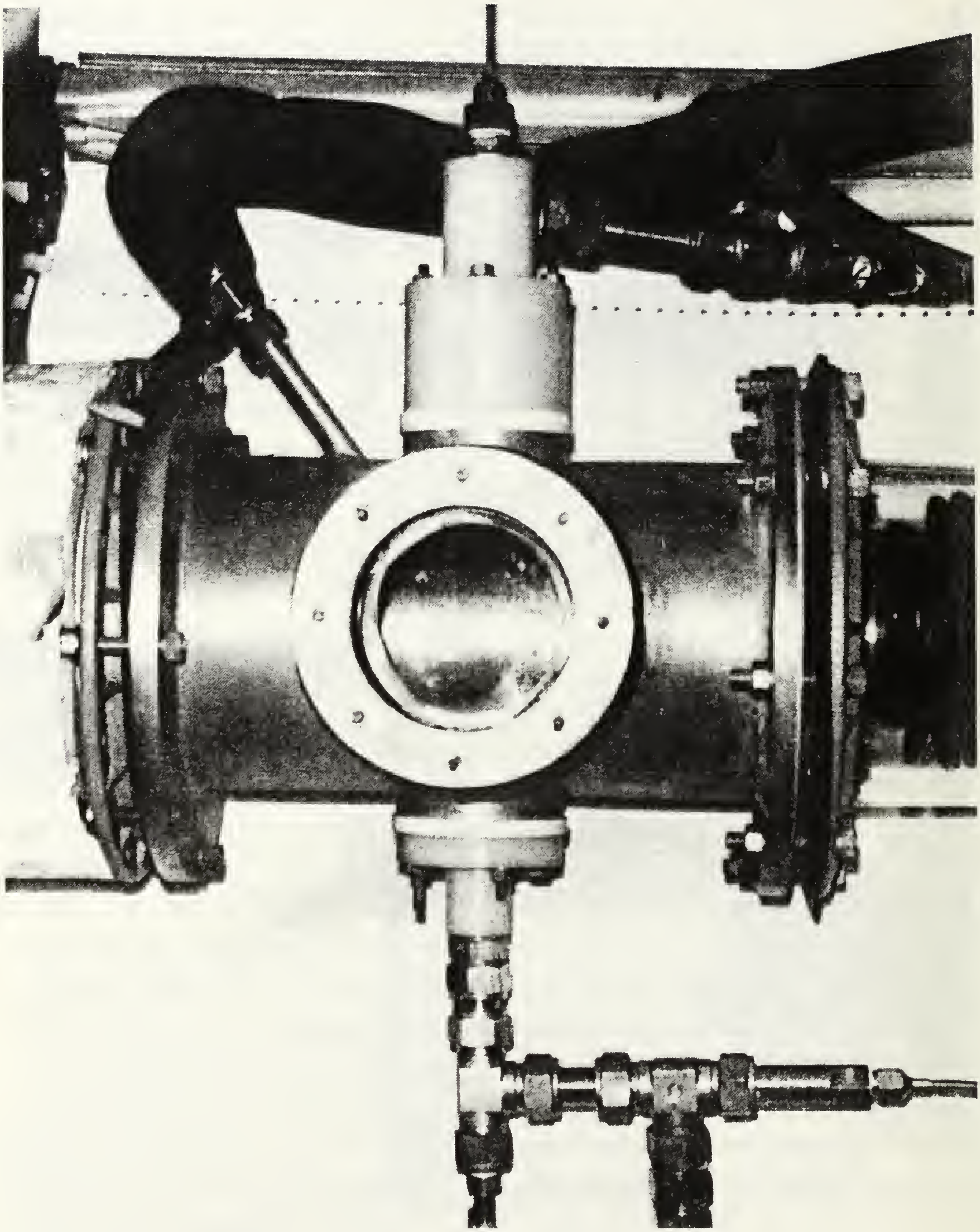

Figure 11. Photograph of Old Test Section Before Modification to Inlet

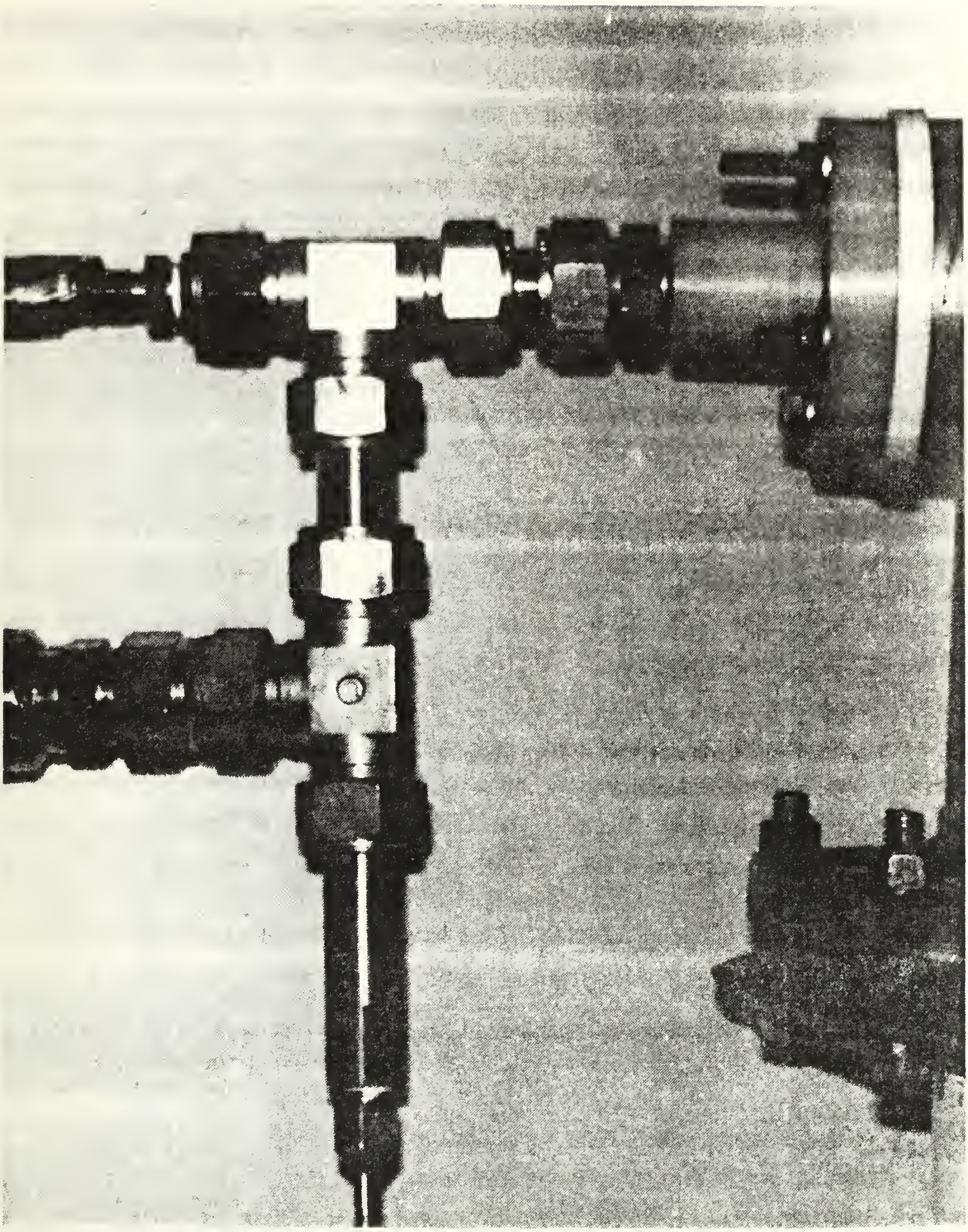

Figure 12. Photograph of Old Test Section Before Modification to Inlet

perimental data for fin spacings between 1.0 and 2.0 mm; this was particularly important since previous experiments had indicated an unexpected dip in the enhancement curve for a fin spacing of 1.5 mm. Secondly, for future inundation experiments, it would be preferable to have two identical tubes placed one above the other in the tube bundle to get more accurate condensate flow patterns. This new small finned tube family gave four matching small tube sets with fin spacings of .25, .5, 1.0 and 1.5 mm fin spacings. A new medium diameter, 1.5 mm fin spacing tube was manufactured for the same reason (with future inundation experiments in mind). The one difference between the new small finned tubes and the old small finned tubes was that the inside bore of the new tubes was slightly 'rifled' due to some difficulties experienced by the manufacturer. Instead of a smooth surface on the inside, they had a roughened surface which might induce additional turbulent mixing. This was of concern since all of the tubes were to be tested with and without the use of spiral inserts and it was felt that the small tube tests without the use of the inserts may differ for the old (smooth bore) small finned tubes and the new (rifled bore) small finned tubes. There was no concern about the tests to be done with the inserts since the effect of the rifling would not be noticed when the insert was present. It was found, however, that the two 'bores' yielded negligible difference in the heat transfer coefficients.

There was one additional finned tube studied in the present investigation. The QMCNPS tube was manufactured to try and copy exactly tests done at the University of London. The diameter was the same as the small family mentioned above. The fins were still rectangular in shape but had a height of 1.59 mm and fin thickness of 0.5 mm. The fin spacing was 1.0 mm.

F. INSERTS

As stated above, all the tubes were tested with and without the spiral inserts. Early investigations had shown that without the use of inserts, the coolant side thermal resistance could be as much as 50 to 60 percent of the overall (ie. vapor to coolant) thermal resistance. A small discrepancy in the coolant side thermal resistance could therefore translate into a substantially larger discrepancy in the outside heat-transfer coefficient. The use of an insert enhances the coolant side heat- transfer coefficient (ie. reduces the thermal resistance) thereby improving the accuracy of the outside heat-transfer coefficient. It also reduces circumferential wall temperature variation and thermal entrance effects by inducing quicker turbulent boundary-layer growth. Photographs of the inserts, designed by Georgiadis [Ref. 27], are shown in Figure 13.

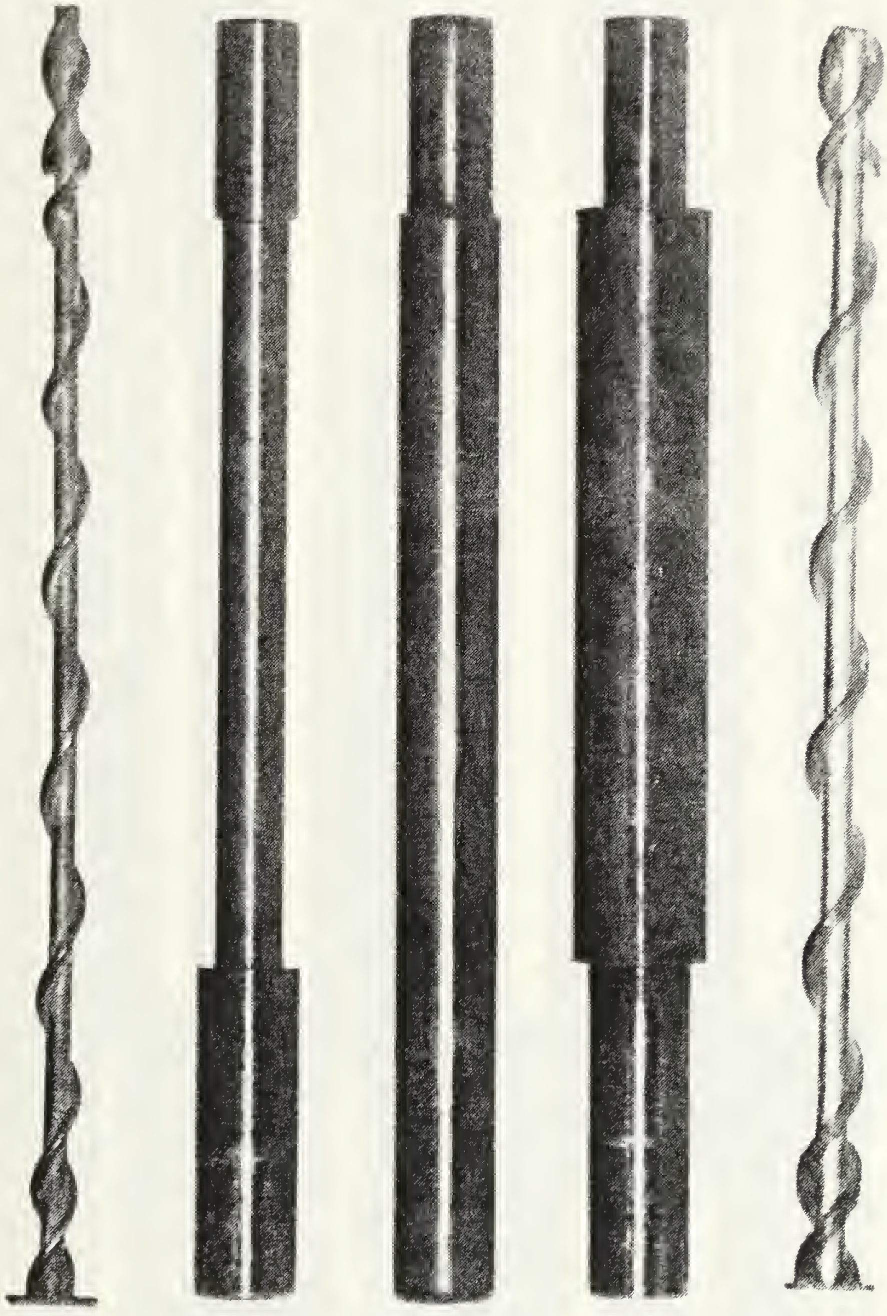

Figure 13. Photograph of smooth tubes and spiral inserts

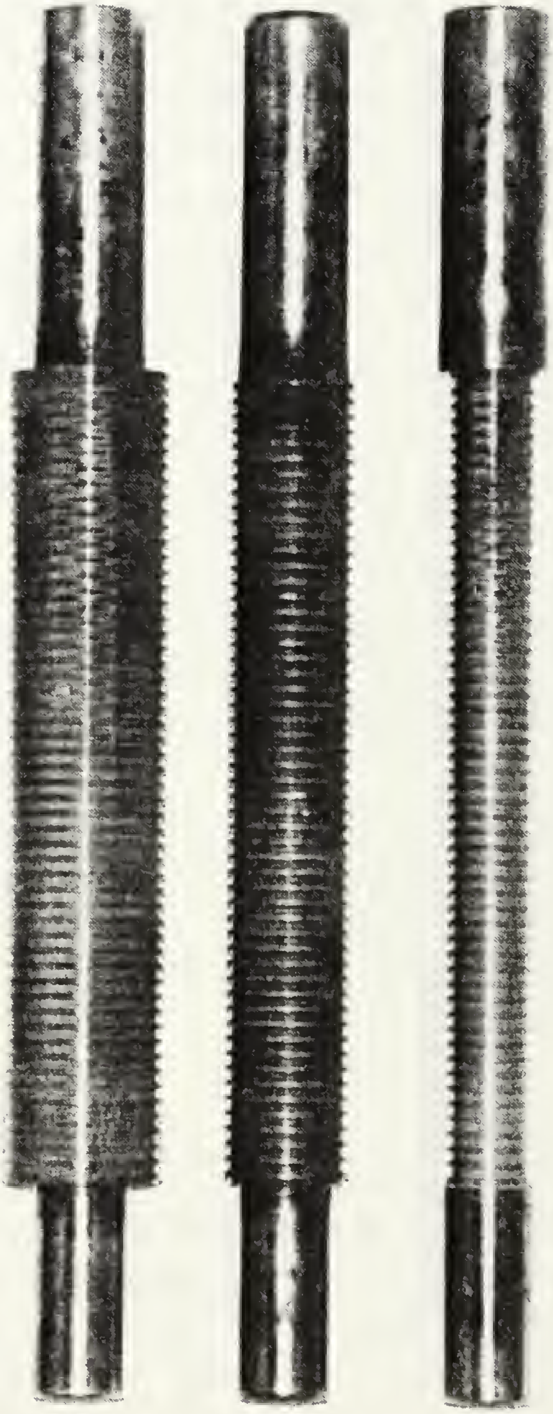

Figure 14. Photograph of tubes with 1.5 mm fin spacing

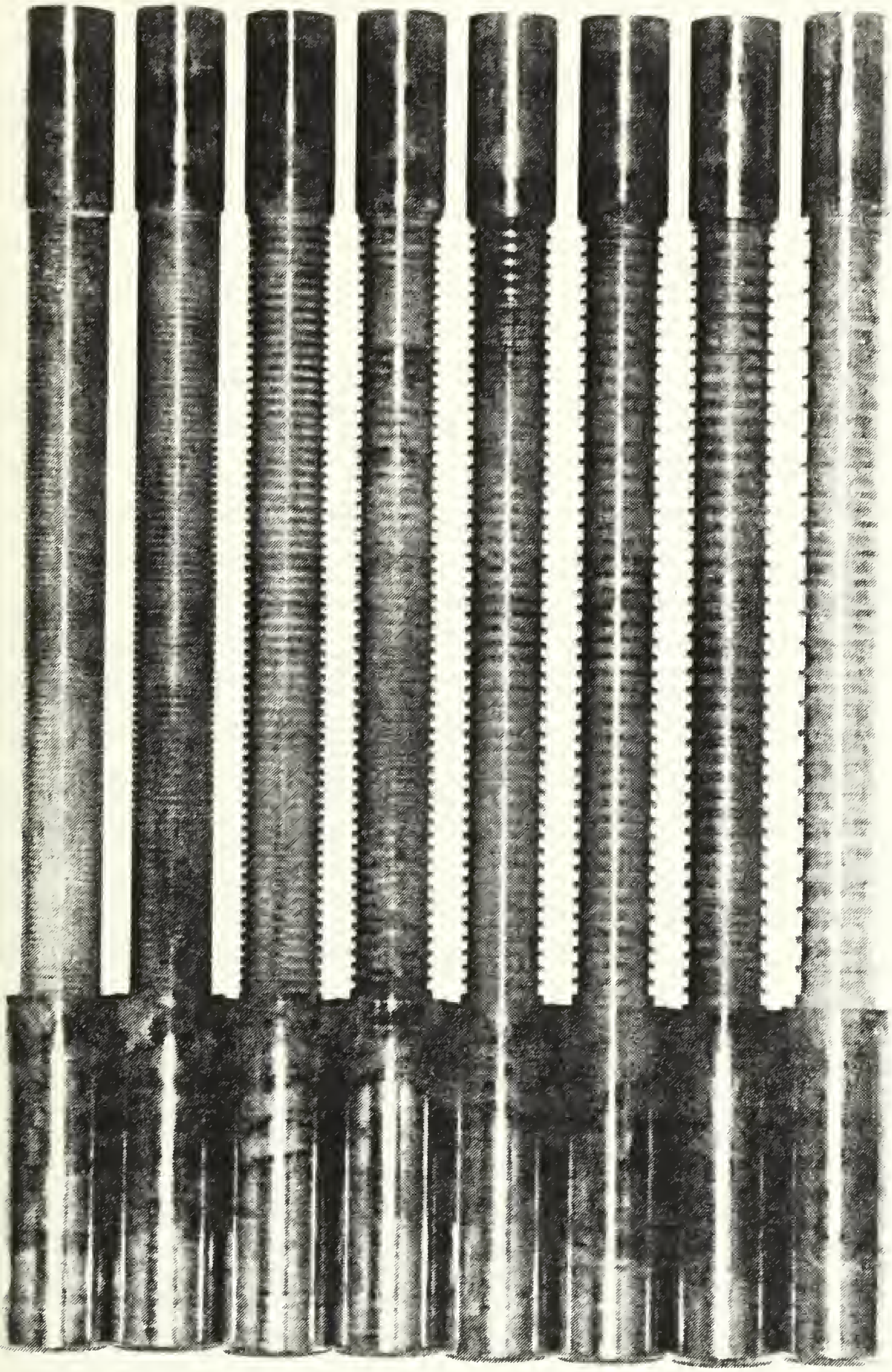

Figure 15. Photograph of small tube family. Fin spacings shown (mm)

Table 1. DIMENSIONS OF TUBES TESTED

Tube	Dr(mm)	Di(mm)	b(mm)	t(mm)	e(mm)
Smooth Tubes					
S088(small)	12.70	9.53	-	-	-
S001(med)	19.05	12.70	-	-	-
S089(large)	25.00	12.70	-	-	-
Old Small Finned Tube Family					
F074	12.70	9.53	0.25	1.0	1.0
F075	12.70	9.53	0.50	1.0	1.0
F076	12.70	9.53	1.0	1.0	1.0
F077	12.70	9.53	1.5	1.0	1.0
F078	12.70	9.53	2.0	1.0	1.0
F079	12.70	9.53	4.0	1.0	1.0
New Small Finned Tube Family					
F090	12.70	9.53	0.25	1.0	1.0
F091	12.70	9.53	0.50	1.0	1.0
F092	12.70	9.53	1.0	1.0	1.0
F093	12.70	9.53	1.25	1.0	1.0
F094	12.70	9.53	1.5	1.0	1.0
F095	12.70	9.53	1.75	1.0	1.0
Medium Finned					
F006(old)	19.05	12.70	1.5	1.0	1.0
F096(new)	19.05	12.70	1.5	1.0	1.0
Large Finned					
F086	25.00	12.70	1.5	1.0	1.0
QMCNPS					
F083	12.70	9.53	1.0	0.5	1.59

The reason that the tubes were tested without the spiral inserts was to enable direct comparison with results from Queen Mary College (QMC) at the University of London where similar research is taking place. All the experimental data at QMC, using steam as the working fluid, were taken without the use of inserts. Although the use of an insert will lead to a higher heat flux, it should not affect the magnitude of the outside heat-transfer coefficient (the outside does not know the cause for the improved heat transfer). significant discrepancies have been found, however, between data taken from QMC and NPS when one data set used an insert (NPS) and the other didn't (QMC). It was felt that a better comparison of results would be achieved if test conditions were duplicated exactly.

G. SYSTEM INTEGRITY

When operating under vacuum conditions, leak tightness of the apparatus is of vital importance. Any non-condensing gases introduced because of a leaking system could lead to inaccurate data. In this investigation, vacuum tests were performed regularly by using the vacuum pump to bring the system pressure down as low as possible (approximately 20 mmHg). The system was then secured and the vacuum pump disconnected. The mercury manometer was monitored overnight for any increase in system pressure. In the past, leak rates yielding an overnight (24 hrs) pressure increase of only 2 mmHg had been obtained. At the start of this investigation, typical leak rates yielded overnight pressure increases up to 50 to 60 mmHg. Location of leaks was accomplished in two ways. First the system was placed under a vacuum and filled with water. Leaks were then indicated by air bubbles entering the apparatus. This method located three leaks in solder joints at the bottom of the auxiliary condenser where the auxiliary cooling water lines penetrated the base plate. The second method involved pressurizing the system to slightly above atmospheric pressure (using argon gas) and then applying diluted soap solution to all joints where leaks were suspected. Leaks were located by bubbling of foaming of the soap solution. This second method located a further leak in a solder joint on the auxiliary condensate drain line. Failure of these solder joints was attributed to an earthquake which recently hit the area. Repair of these solder joints resulted in a vacuum tight system , bringing the overnight pressure increase back down to less than 2 mmHg rise in a 24 hour period.

The presence of non-condensing gases during an experiment under vacuum conditions was a good indication of a leak. By comparing the actual vapor temperature measured by the thermocouple above the test tube and the calculated vapor temperature corresponding to the system pressure indicated by the manometer, the data reduction program could prompt the operator to energize the vacuum pump if the difference indicated a percentage of non-condensing gases greater than 0.5 %.

IV. EXPERIMENTAL PROCEDURES AND DATA REDUCTION

A. EXPERIMENTAL PROCEDURES

The condensation of steam on copper tubes has a tendency to occur in the dropwise mode due to the poor wetting characteristics of water. In order to ensure that filmwise condensation took place, each tube had to be chemically treated prior to installation in the test section as follows:

1. Clean the internal and external surfaces of the tube using a soft brush and mild soap (such as dishwashing detergent) and water to remove any oils or dirt which may have been deposited on the tube.
2. Place the tube in a steam bath.
3. Mix equal amounts of ethyl alcohol and sodium hydroxide. Heat the solution to about 80 degree C (until watery).
4. Apply the solution to the tube with a small paint brush and retain the tube in the steam bath. If the tube has not been previously treated, apply a coating of the solution every 10 minutes for an hour. If the tube has been previously treated, apply a coating every 5 minutes for a period of 20 minutes. A black oxide layer should form.
5. Remove the tube from the steam bath and thoroughly rinse the tube with distilled water to remove any excess solution. Install the tube in the test section as soon as possible. After treatment, the tube surface should not be touched. Oils and dirt from hands will contaminate the tube which could result in partial dropwise condensation.

The black oxide layer which is formed exhibits high wetting characteristics and its thermal resistance is negligible.

Following cleaning and treating, the test tube was installed in the test section. Tests were performed with and without the spiral insert. The system was then started in accordance with procedures outlined in Appendix B. Once the system was started and equilibrium conditions had been obtained, data could then be taken. As mentioned in the startup procedures, system pressure (measured by the mercury manometer) and system temperature (measured from the vapor thermocouple) were closely monitored throughout not only to ensure safety, but also to maintain steady operating conditions (equilibrium). The desired operating conditions for conducting tests with steam at vacuum and atmospheric pressure are listed in Table 2.

When equilibrium had been reached, the system was left for approximately thirty minutes before any data were taken in order to monitor any changes. During this thirty

Table 2. OPERATING CONDITIONS

Pressure	Thermocouple Reading (microvolts)	Measured Temperature (deg C)	Measured Pressure (mm Hg)	Vapor Velocity (m/s)
Vacuum	1977	48	85	2.0
Atmospheric	4277	100	765	1.0

minute period, all thermocouple and quartz thermometers readings were checked to ensure proper operation. Sample data were then taken to check for non-condensing gases. Adjustments to the auxiliary cooling water flow rate maintained the desires system pressure. Eight different cooling water flow rates through the condenser tube were used for each test. The flow rates were selected so as to give the widest possible range of cooling water temperature rise. The cooling water flow rates used (indicated as a percent on the flowmeter) were: 20, 26, 35, 45, 54, 62, 70, 80 and then back to 20. Two data points were taken at each flow rate giving a total of 18 data points for each tube. The last two data points taken at 20% were compared with the first two data points taken at the same flow rate. If they did not compare well (within approximately 5 %) the entire data set was rejected. Reasons for differences between the first and last data points could indicate either the occurrence of partial dropwise condensation or increased concentrations of non-condensable gases. These same eight flow rates were used for both the medium and large diameter tubes when tested with and without an insert (both tubes had the same internal diameter). For the small diameter tubes, the flow rates used were slightly different: 20, 26, 33, 40, 47, 54, 61, 66 and 20 percent. The reason for this is that with the insert, flow rates above 70 percent could not be attained due to choking of the flow. Consequently, to enable direct comparison, these flow rates were adopted for the small tube both with and without the insert. Multiple tests for each tube at each operating condition were done to ensure repeatability.

B. DATA REDUCTION PROCEDURES

1. Development

The overall thermal resistance to heat transfer from the vapor to the cooling water is the sum of the vapor side resistance, the tube wall resistance, and the coolant side resistance. The vapor side resistance and the coolant side resistance are convective in nature. These resistances can be expressed by:

$$R_i = \frac{1}{h_i A_i} \tag{4.1}$$

$$R_o = \frac{1}{h_o A_o} \tag{4.2}$$

where:

R_i = *inside resistance to heat transfer*

h_i = *inside heat transfer coefficient*

A_i = *effective inside surface area*

R_o = *outside resistance to heat transfer*

h_o = *outside heat transfer coefficient*

A_o = *effective outside surface area*

The effective inside surface area includes not only the inside surface area corresponding to the active condensing length but also the inside surface area corresponding to the insulated inlet and outlet portions of the tube. These portions act as annular fins which remove heat by axial conduction. The extended fin assumption and associated fin efficiencies are used to account for these inlet and outlet portions.

$$A_i = \pi D_i (L + L_1 \eta_1 + L_2 \eta_2) \tag{4.3}$$

where:

D_i = *inside diameter of tube*

L = *length of exposed tube(active condensing length)*

L_1 = *length of inlet portion of tube*

L_2 = *length of outlet portion of tube*

η_1 = *fin efficiency of inlet portion of tube*

η_2 = *fin efficiency of outlet portion of tube*

The actual outside surface area varies with each different fin spacing. It is therefore customary with finned tubes to use an effective outside surface area.

$$A_o = \pi D_r L \tag{4.4}$$

where:

D_r = *root diameter*

The tube wall resistance (assuming uniform radial conduction) is:

$$R_w = D_r \frac{\ln \frac{D_r}{D_i}}{2k_m} \tag{4.5}$$

where:

$R_w = tube\ wall\ resistance$

$k_m = thermal\ conductivity\ of\ copper$

The overall thermal resistance is given by:

$$\frac{1}{U_o A_o} = R_i + \frac{R_w}{A_o} + R_o \tag{4.6}$$

where U_o is the overall heat transfer coefficient. Substituting Equations (4.1), (4.2) and (4.5) gives:

$$\frac{1}{U_o A_o} = \frac{1}{h_i A_i} + \frac{R_w}{A_o} + \frac{1}{h_o A_o} \tag{4.7}$$

The overall thermal resistance can be determined by calculating the total heat transfer rate Q. The total heat transfer rate across the tube is determined by measuring the inlet and outlet temperatures an mass flow rate of the cooling water through the test tube.

$$Q = U_o A_o (LMTD) \tag{4.8}$$

$$Q = \dot{m} c_p (T_2 - T_1) \tag{4.9}$$

where:

$Q = heat\ transfer\ rate$

$\dot{m} = mass\ flow\ rate\ of\ coolant$

$c_p = specific\ heat\ of\ coolant\ at\ constant\ pressure$

$T_1 = coolant\ inlet\ temperature$

$T_2 = coolant\ outlet\ temperature$

$LMTD = log\ mean\ temperature\ difference\ defined\ in\ Equation$ (1.2)

The inlet and outlet cooling water temperatures were measured using quartz thermometers. Additionally, a correction factor was applied to the outlet temperature to account for viscous heating of the cooling water (this was independently correlated to coolant flowrate). All cooling water properties were calculated using an average of the inlet and outlet coolant temperatures. The mass flow rate was determined from a correlation relating percent readings from the flowmeter to actual flow rates in the tube. From this mass flow rate, the cooling water velocity through the tube could be found.

$$\dot{m} = \rho A_c V \tag{4.10}$$

where:

ρ = *test tube cooling water density*

A_c = *cross sectional area of test tube w/o insert*

V = *test tube average cooling water velocity*

Once the total heat transfer rate has been calculated from Equation (4.9), the overall thermal resistance and hence the overall heat transfer coefficient can be determined using Equation (4.8). This leaves only two unknowns in Equation (4.7), the inside and outside heat transfer coefficients.

2. Modified Wilson Plot

The most accurate means to determine the inside and outside heat transfer coefficients is to measure directly the vapor temperature, the tube wall temperature, and the coolant temperature. It is not difficult to measure the vapor and coolant temperatures. In order to measure the tube wall temperature directly, instrumented tubes fitted with wall thermocouples must be used. Using the direct temperature values from the instrumented tubes, the inside and wall resistances can be calculated and subtracted from the overall resistance (calculated as above) leaving only the outside resistance from which the outside heat transfer coefficient can easily be obtained. Unfortunately, the manufacture of these instrumented tubes is both costly, time consuming and impractical with the large number of tubes used in the present investigation.

An alternative to using instrumented tubes is to employ the "Modified Wilson Plot" technique. The Modified Wilson Plot is a mathematical technique which provides the inside and outside coefficients simultaneously.

Use of the Modified Wilson Plot requires that the form of the inside and outside heat transfer coefficients be known. During this study (and past studies at NPS) the Sieder-Tate correlation and Nusselt analysis were used to represent the inside and outside coefficients respectively. For the inside, the Sieder-Tate correlation [Ref. 28] is given by:

$$h_i = C_i \frac{k_c}{D_i} Re^{0.8} Pr^{0.333} \left(\frac{\mu_c}{\mu_w} \right)^{0.14} = C_i \Omega \tag{4.11}$$

where:

$C_i =$ *Sieder − Tate leading coefficient*

$k_c =$ *thermal conductivity of cooling water*

$Re =$ *Reynolds Number*

$Pr =$ *Prandtl Number*

$\mu_c =$ *dynamic viscosity of cooling water at bulk temperature*

$\mu_w =$ *dynamic viscosity of cooling water at inner wall temperature*

The term $\left(\frac{\mu_c}{\mu_w} \right)^{0.14}$ was added by Sieder and Tate to the correlation of Colburn [Ref. 29] to account for strong viscosity variation between the inner wall and the bulk coolant. For the outside heat-transfer coefficient, the simple Nusselt analysis [Ref. 18] yields

$$h_o = \alpha \left[\frac{k_f^3 \rho_f^2 g h_{fg}}{\mu_f D_o q} \right]^{\frac{1}{3}} = \alpha F \tag{4.12}$$

where:

$\alpha =$ *dimensionless Nusselt coefficient*

$k_f =$ *thermal conductivity of condensate film*

$\rho_f =$ *density of condensate film*

$\mu_f =$ *dynamic viscosity of condensate film*

$h_{fg} =$ *specific enthalpy of vaporization*

$q =$ *heat flux based on outside area* $\left(\frac{Q}{A_o} \right)$

Substituting Equations (4.11) and (4.12) into Equation (4.7) and rearranging gives:

$$\left[\frac{1}{U_o} - R_w \right] F = \frac{A_o F}{C_i \Omega A_i} + \frac{1}{\alpha} \tag{4.13}$$

Equation (4.12) is a linear equation with two unknowns, C_i and α . If we let

$$Y = \left[\frac{1}{U_o} - R_w \right] F, \tag{4.14}$$

$$X = \frac{A_o F}{A_i \Omega} , \tag{4.15}$$

$$C_i = \frac{1}{m} , \tag{4.16}$$

and

$$\alpha = \frac{1}{b} \tag{4.17}$$

Equation (4.13) then becomes

$$Y = mX + b \tag{4.18}$$

Because Ω and F are both temperature dependent, they have to be determined iteratively. A least-squares fit of Equation (4.18) is then made to determine C_i and α.

Once the Sieder-Tate coefficient has been computed, the inside heat transfer coefficient is calculated using Equation (4.11). The outside heat transfer coefficient is then found by rearranging Equation (4.7) to get

$$\frac{1}{h_o} = \frac{1}{U_o} - \left[\frac{A_o}{h_i A_i} + R_w \right] \tag{4.19}$$

Previous work at NPS used instrumented smooth tubes to determine the outside heat transfer coefficient and non-instrumented smooth tubes with the Modified Wilson Plot technique to determine the outside heat transfer coefficient. The results of the two different methods showed that, when used properly, the Modified Wilson Plot technique gave results consistent with those obtained by the instrumented tubes. A higher degree of accuracy can be achieved if the inside and outside resistances are comparable. To equalize the resistances (ie. to reduce the inside resistance) a spiral insert has been used whenever the inside resistance is dominant, as is the case when steam is the working fluid.

3. Enhancement Ratio

From simple Nusselt theory we know

$$q = a \Delta T_f^n . \tag{4.20}$$

where:

q = *the heat flux*

a = *proportionality constant*

ΔT_f = *the temperature drop between the vapor and the mean outer wall temperature*

We also know that

$$q = h\Delta T_f. \tag{4.21}$$

where h is the outside heat transfer coefficient. Therefore

$$h = a\Delta T_f^{n-1}. \tag{4.22}$$

The enhancement ratio for a finned tube represents the enhancement (ie. the improvement) in heat transfer due to the fins as compared to a smooth tube. Nusselt theory predicts a value of 0.75 for n. Therefore, n was set equal to 0.75 so that an enhancement ratio (based on a constant heat flux) could be determined.

$$\varepsilon_q = \frac{h_{of}}{h_{os}} = \frac{a_f}{a_s} = \frac{\alpha_f F_f}{\alpha_s F_s} \tag{4.23}$$

The subscripts f and s refer to finned and smooth respectively. If the heat flux across the condensate film is held constant for both finned and smooth tubes, then their values of F will also be the same (see Equation (4.12)). Equation (4.23) then becomes

$$\varepsilon_q = \frac{\alpha_f}{\alpha_s}. \tag{4.24}$$

The values of α_f and α_s are computed from the Modified Wilson Plot. The enhancement ratio based on a constant vapor side temperature drop can be shown to be (from Nusselt theory):

$$\varepsilon_{\Delta T} = \varepsilon_q^{0.75} = \left(\frac{\alpha_f}{\alpha_s}\right)^{0.75} \tag{4.25}$$

Looking at Equation (4.12), it can be seen that the effect of tube diameter appears only in the value of F and therefore α should be independent of tube root diameter. Van Petten [Ref. 4] was the first investigator at NPS to investigate the effects of tube diameter. Based on the above theory, he calculated enhancements for three different diameter finned tube families using only one α he obtained for a medium smooth tube.

Coumes [Ref. 7], in order to confirm the theoretical conclusion that α was independent of tube diameter, tested a small diameter smooth tube and found an α which differed slightly from the medium smooth tube α. This investigation, in order to complete the picture, tested a large diameter smooth tube and again found a slightly different α. It is believed that the reason for the variation of α with tube diameter has to do with the fact that Nusselt theory assumes zero vapor velocity. Vapor velocities in the NPS investigations, which are assumed negligible but are approximately 1 to 2 m/s, apparently do affect the values of α slightly. It is therefore necessary to calculate enhancement ratios for finned tubes of different diameters based on their corresponding smooth tube values. This will be discussed further in the following chapter where specific results are presented.

V. RESULTS AND DISCUSSION

A. INTRODUCTION

Experimental data were taken on the tubes described in Chapter III using the procedures discussed in Chapter IV and Appendix B. Throughout the testing, repeatability of the data was a primary concern. As discussed in Chapter III, poor repeatability of data with previous investigations was one of the reasons that the new test section was replaced with the old test section. In addition, tests were repeated on each tube to ensure consistency in the data-taking. The previous investigations used for comparison were those of Van Petten [Ref. 4] and Coumes [Ref. 7], the two most recent investigators on this project.

The smooth tube results are discussed first since they are the basis for the calculation of the enhancement ratio. The present finned tube results for the medium and large diameter tubes are then presented to show the good agreement with previous data. The small diameter finned tube family, which was the main focus of this investigation, is then be discussed. Within this section, the calculation of the inside and outside heat-transfer coefficients and the enhancement ratio are included. This shows comparisons of the old small finned tube family with previous data; it also shows comparisons for the new small finned tube family with the old small finned tube family. All the above results are for tests done using a spiral insert. The results obtained without the use of a spiral insert are then be presented and discussed. This also includes a discussion of significant differences found previously between the QMC and the QMCNPS data and give some possible causes.

B. SMOOTH TUBE RESULTS

Figures 16 thru 21 show the repeatability for the three smooth tubes tested at vacuum and atmospheric conditions. The graphs plot the outside heat-transfer coefficient against the average temperature drop across the condensate film (taken as the difference in the vapor temperature and the average outside tube wall temperature). The solid line represents the equation of Nusselt given by:

$$h_o = .728\left[\frac{k_f^3 \rho_f^2 g h_{fg}}{\mu_f D_o \Delta T_f}\right]^{\frac{1}{4}} \tag{5.1}$$

The dashed line drawn through the data represent a least squares fit of the equation:

$$h_o = a\Delta T^{-0.25} \tag{5.2}$$

The good repeatability is demonstrated by the fact that the data from previous investigations agrees very well with the present data where applicable. It should be noted that when Van Petten first conducted condensation tests to determine the effect of tube root diameter on the enhancement ratio for finned tubes, he only tested one smooth tube (the medium diameter tube) to calculate the enhancement ratios for all three diameter finned tube families. His reasoning was based on the Nusselt analysis, where vapor velocity is neglected and the value of α for a smooth tube is independent of tube diameter (see Equation (4.12)). Coumes later found, as a result of testing a small diameter smooth tube in addition to a medium diameter smooth tube, that there is a dependence of α on tube diameter for a smooth tube. The reasoning for this is that although vapor velocity is assumed negligible in our analysis, there is a slight vapor velocity (1-2 m/s) which does appear to affect the value of α . The trend shows α increases as tube diameter decreases. This is not completely unexpected though. A correlation developed by Fujii et al. [Ref. 30] accounts for the variation in outside heat-transfer coefficient of a smooth tube with vapor velocity.. It states:

$$Nu\tilde{Re}^{-\frac{1}{2}} = .96F_f^{\frac{1}{5}} \tag{5.3}$$

where

$$F_f = \frac{gD_o\mu_f h_{fg}}{U_\infty^2 k_f \Delta T} \tag{5.4}$$

$\tilde{Re}$ is the two phase Reynolds number so called because it involves condensate properties and vapor velocity. Manipulation of these equations does show that α is in fact inversely proportional to the smooth tube diameter. This dependence of α on tube diameter can also be seen in Figures 16 thru 21. As the tube diameter increases, the least squares line drawn through the data approaches the Nusselt line or as the tube diameter increases, the value of α approaches 0.728 (the value of α for the Nusselt analysis).

Because the present investigation included the calculation of the enhancement of large diameter finned tubes (in addition to small and medium diameter finned tubes), a large diameter smooth tube also had to be manufactured and tested. All three diameter smooth tubes were tested during the present investigation and the values of α obtained for tests at vacuum and atmospheric conditions are listed in Table 3. Table 3 shows that, for a given tube diameter, α increases as the operating pressure increases; it also shows that, for a given operating pressure, α decreases with increasing tube diameter.

Figures 22 and 23 show the dependence of the outside heat-transfer coefficient on the tube diameter. This can also be predicted by the Nusselt analysis (Equation (5.1)).

Table 3. SUMMARY OF SMOOTH TUBE ALPHAS (WITH INSERT)

Diameter	Vacuum	Atmospheric
Small	0.953	1.008
Medium	0.792	0.889
Large	0.779	0.895

C. MEDIUM AND LARGE DIAMETER FINNED TUBES

Figures 24 and 25 show the repeatability of data taken for the medium diameter tubes at vacuum and atmospheric conditions. The only medium diameter tube fin spacing tested in the present investigation was 1.5 mm. The 1.5 mm fin spacing medium diameter tube tested during previous investigations was tube number F006. Tube number F096 is a newly manufactured tube which is exactly the same as tube F006. It was manufactured in order to support future condensate inundation experiments. Consequently, it should yield the same results as tube F006; and as can be seen from the graphs, the agreement is very close (to within 10 %). The repeatability for all tests done in this investigation was always slightly better under vacuum test conditions probably due to the low saturation temperature.

Figures 26 and 27 show the repeatability for the large diameter finned tube with fin spacing 1.5 mm (Tube F083). Van Petten was the only previous investigator to test the large diameter finned tubes. The repeatability is again better at vacuum conditions but for both pressure conditions is within 10%. The uncertainty bands in Figures 24 and 25 show that the uncertainty of the data decreases as the average temperature drop across the film increases. What is actually happening is that at low values of ΔT_f, the uncertainty is high. As we increase the temperature drop across the film (by decreasing the coolant temperature rise) the uncertainty gets smaller. But at very high values of ΔT_f (very low coolant temperature rises), the uncertainty starts to increase again. The uncertainty analysis is described in Appendix C. Because of this, we would expect the

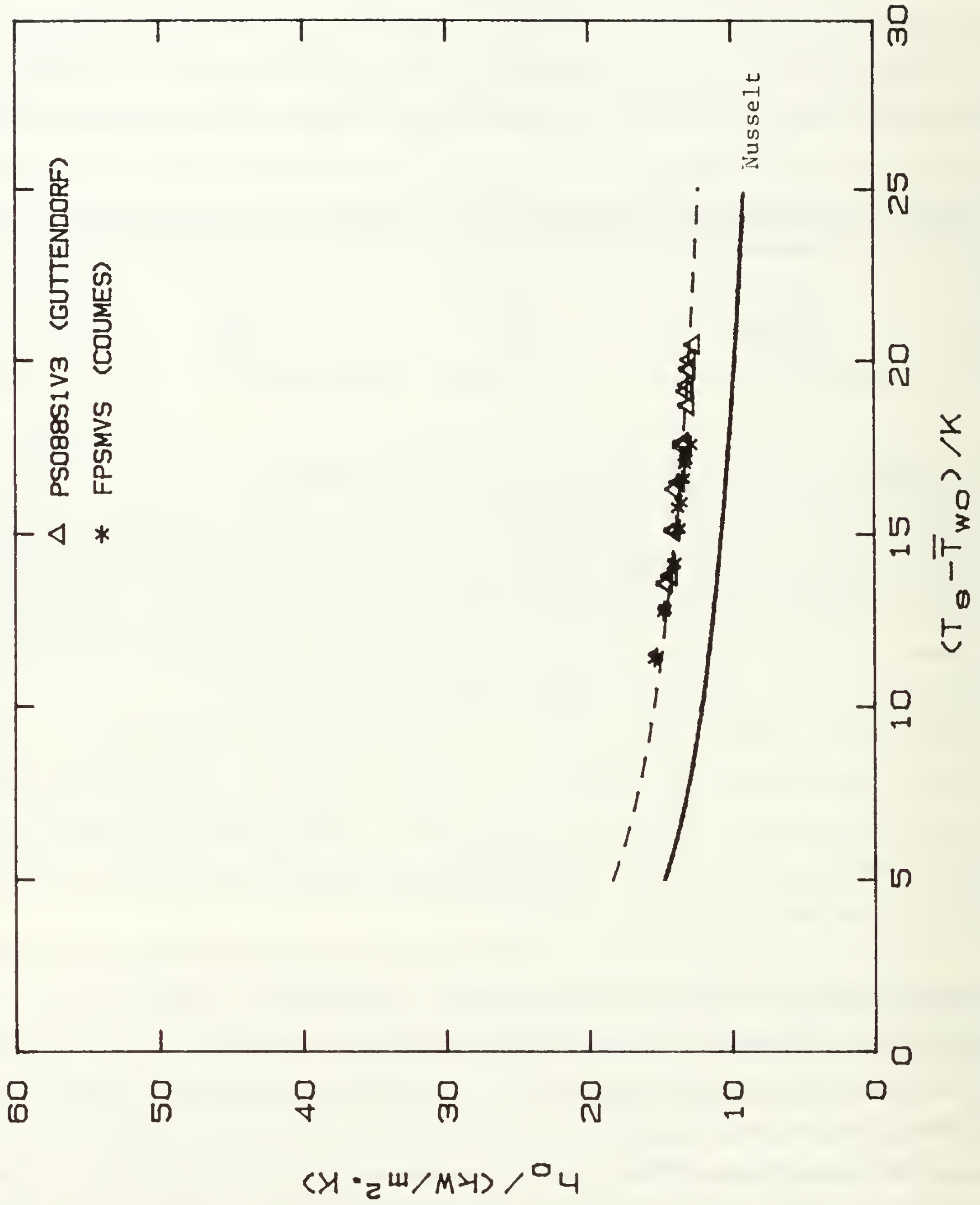

Figure 16. Repeatability of Steam Heat Transfer Coefficients for the Small Smooth Tube (S088) at Vacuum Conditions

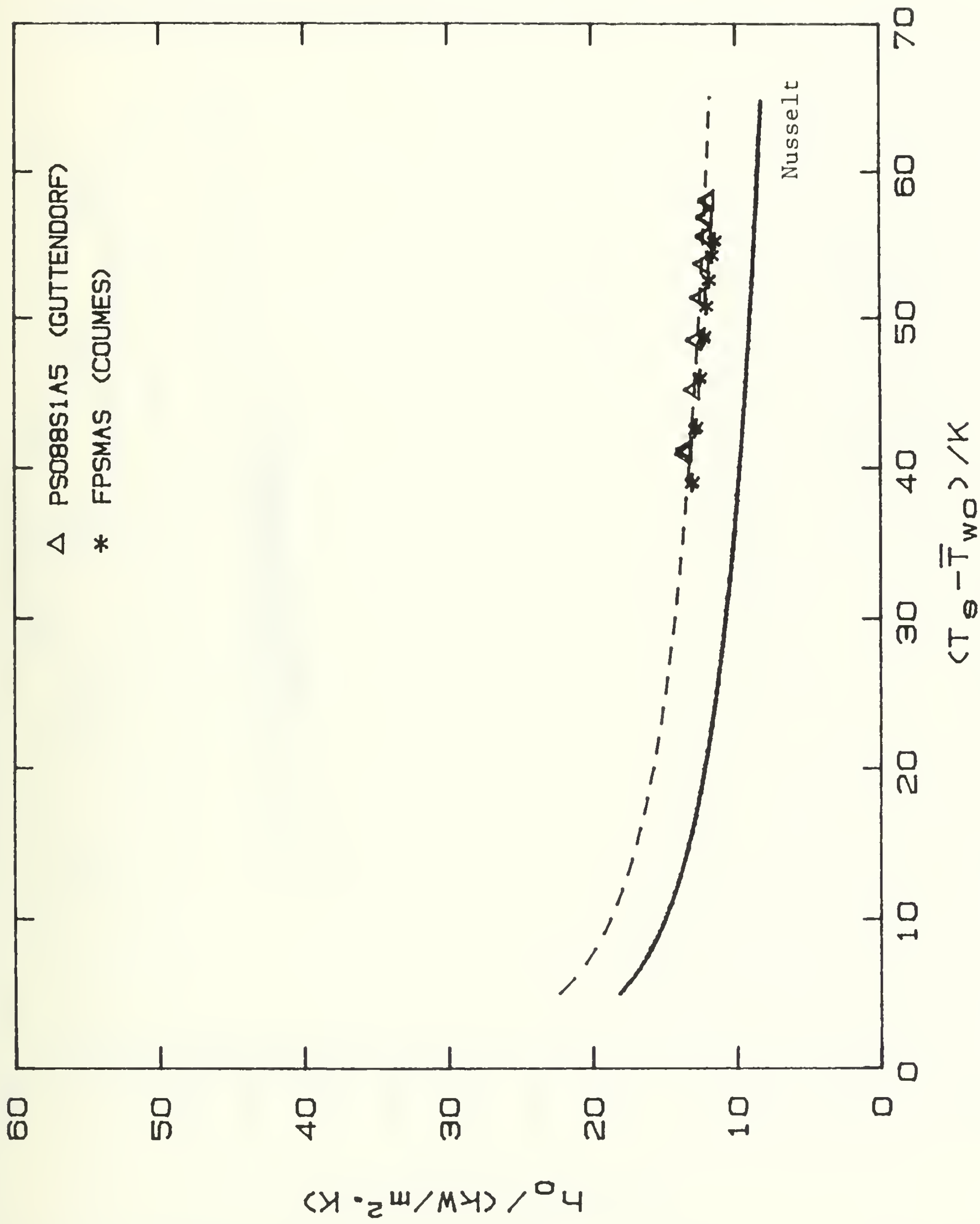

Figure 17. Repeatability of Steam Heat Transfer Coefficients for the Small Smooth Tube (S088) at Atmospheric Conditions

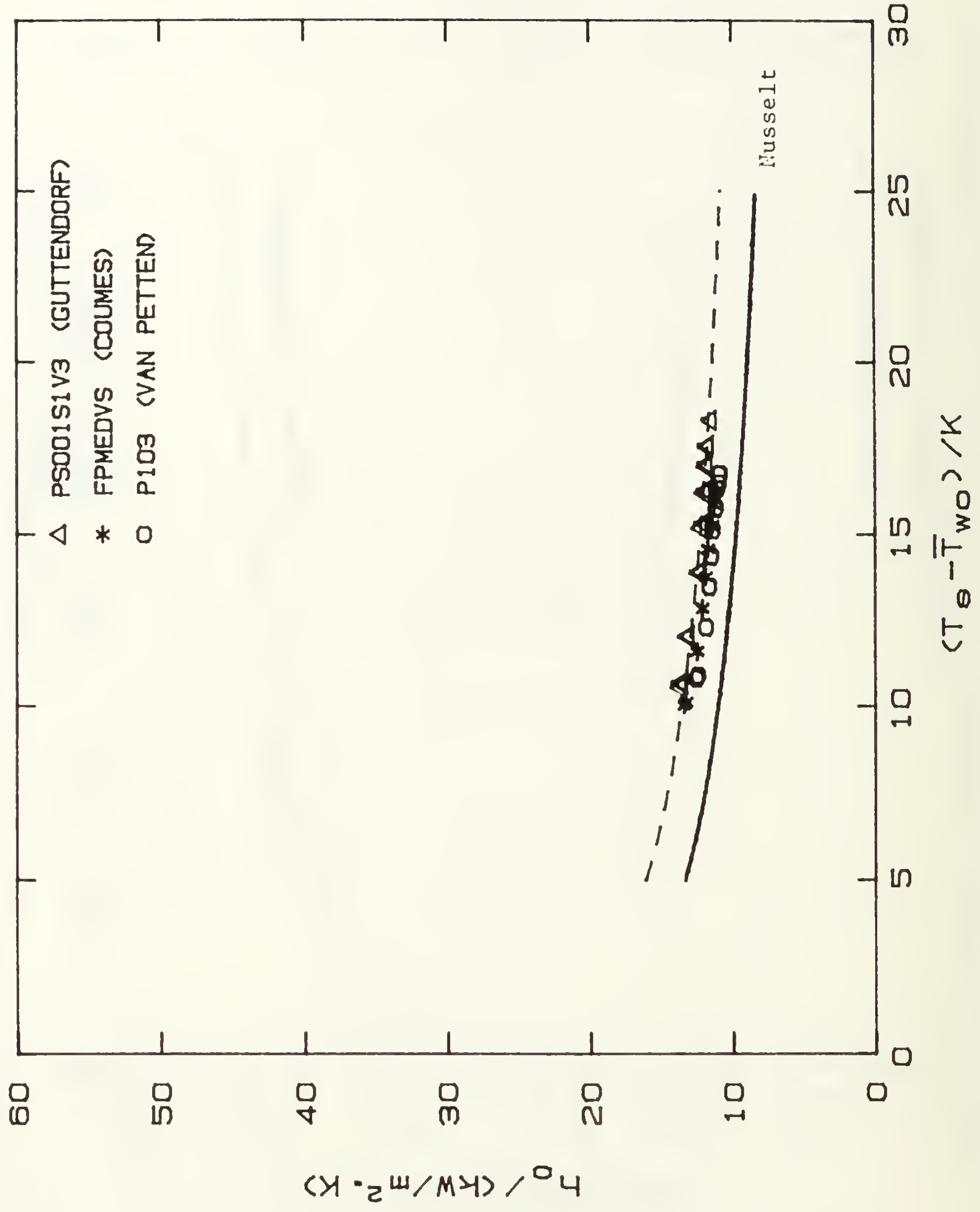

Figure 18. **Repeatability of Steam Heat Transfer Coefficients for the Medium Smooth Tube (S001) at Vacuum Conditions**

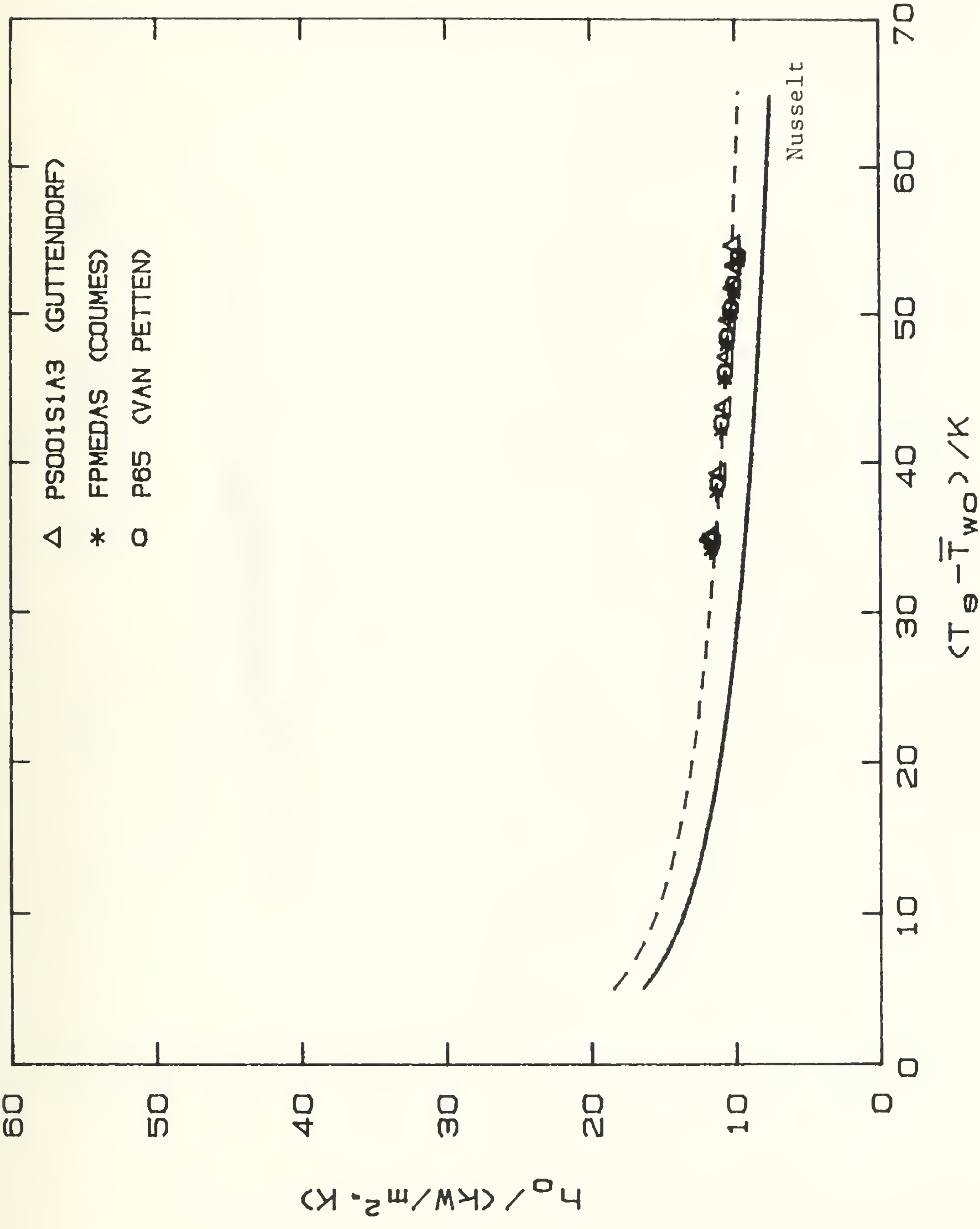

Figure 19. **Repeatability of Steam Heat Transfer Coefficients for the Medium Smooth Tube (S001) at Atmospheric Conditions**

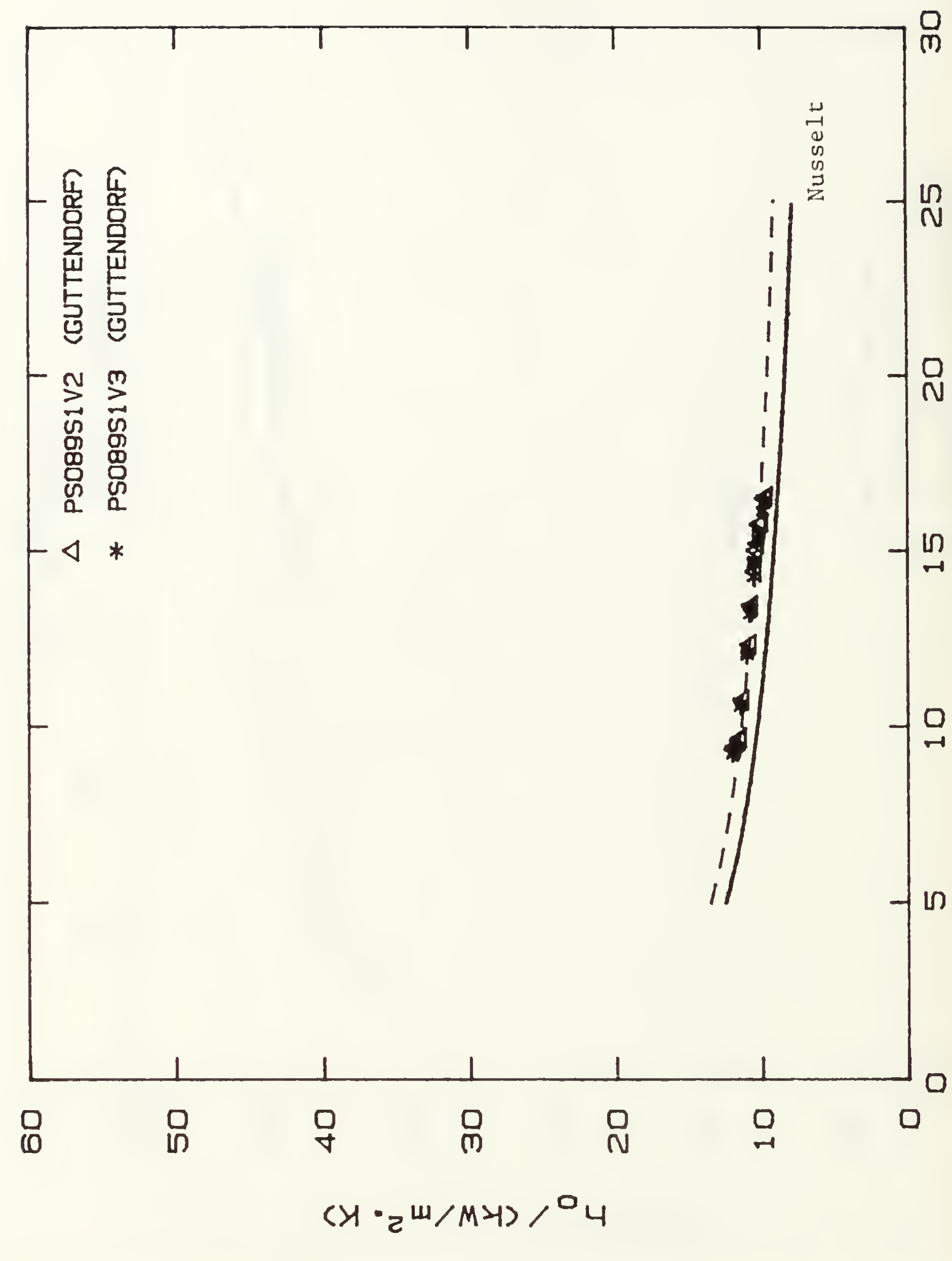

Figure 20. Repeatability of Steam Heat Transfer Coefficients for the Large Smooth Tube (S089) at Vacuum Conditions

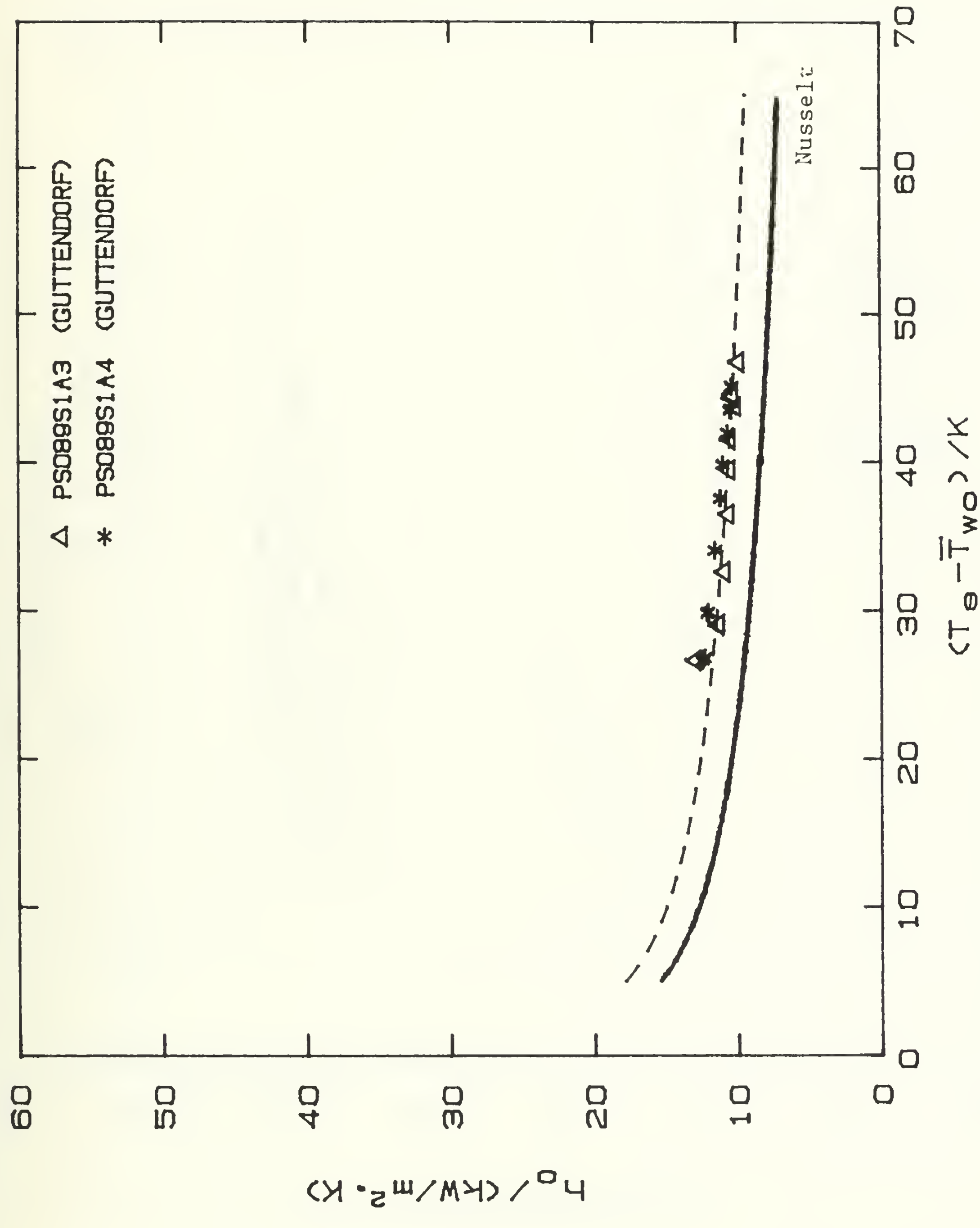

Figure 21. Repeatability of Steam Heat Transfer Coefficients for the Large Smooth Tube (S089) at Atmospheric Conditions

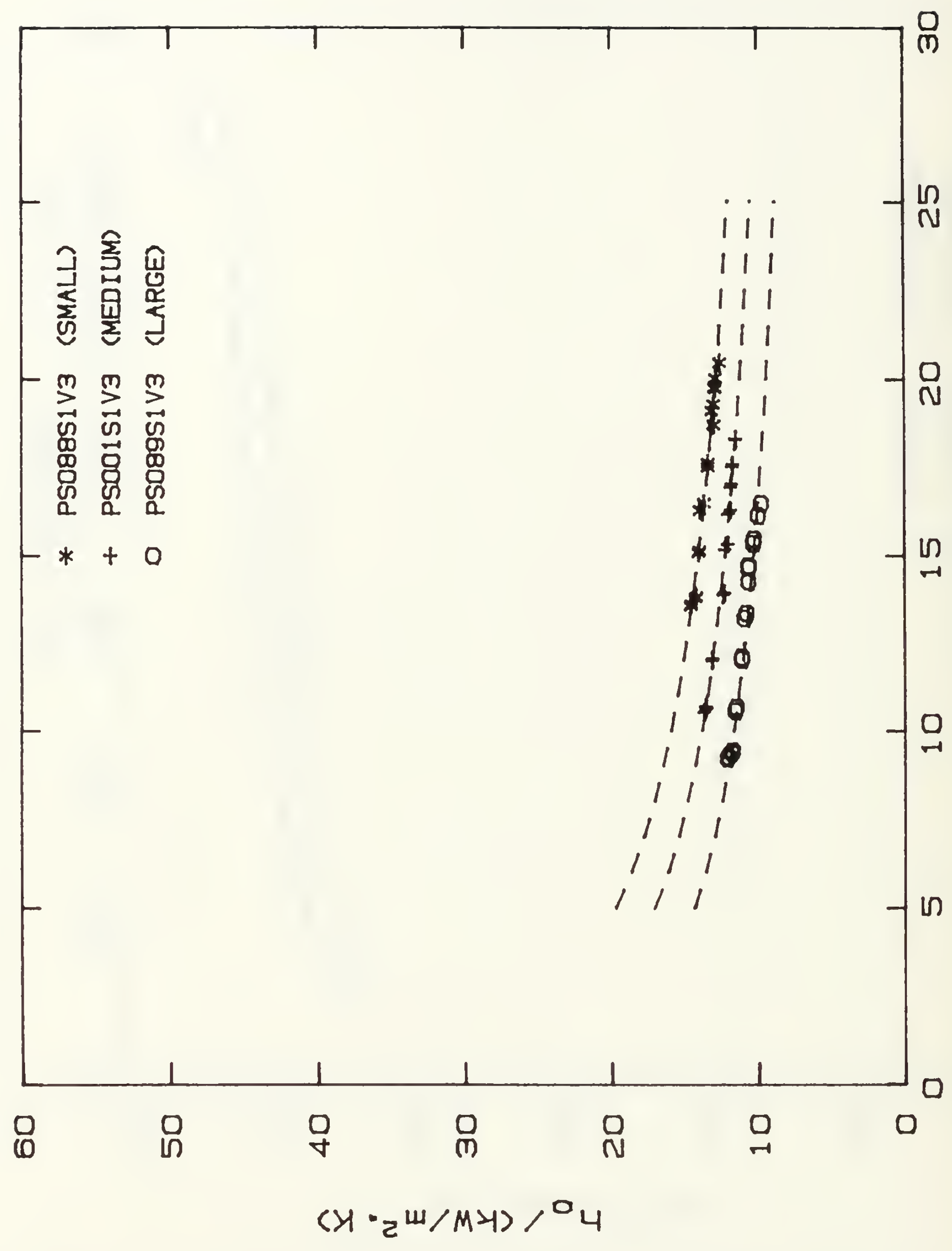

Figure 22. Dependence of Steam Heat Transfer Coefficients on Tube Diameter at Vacuum Conditions (Smooth Tubes)

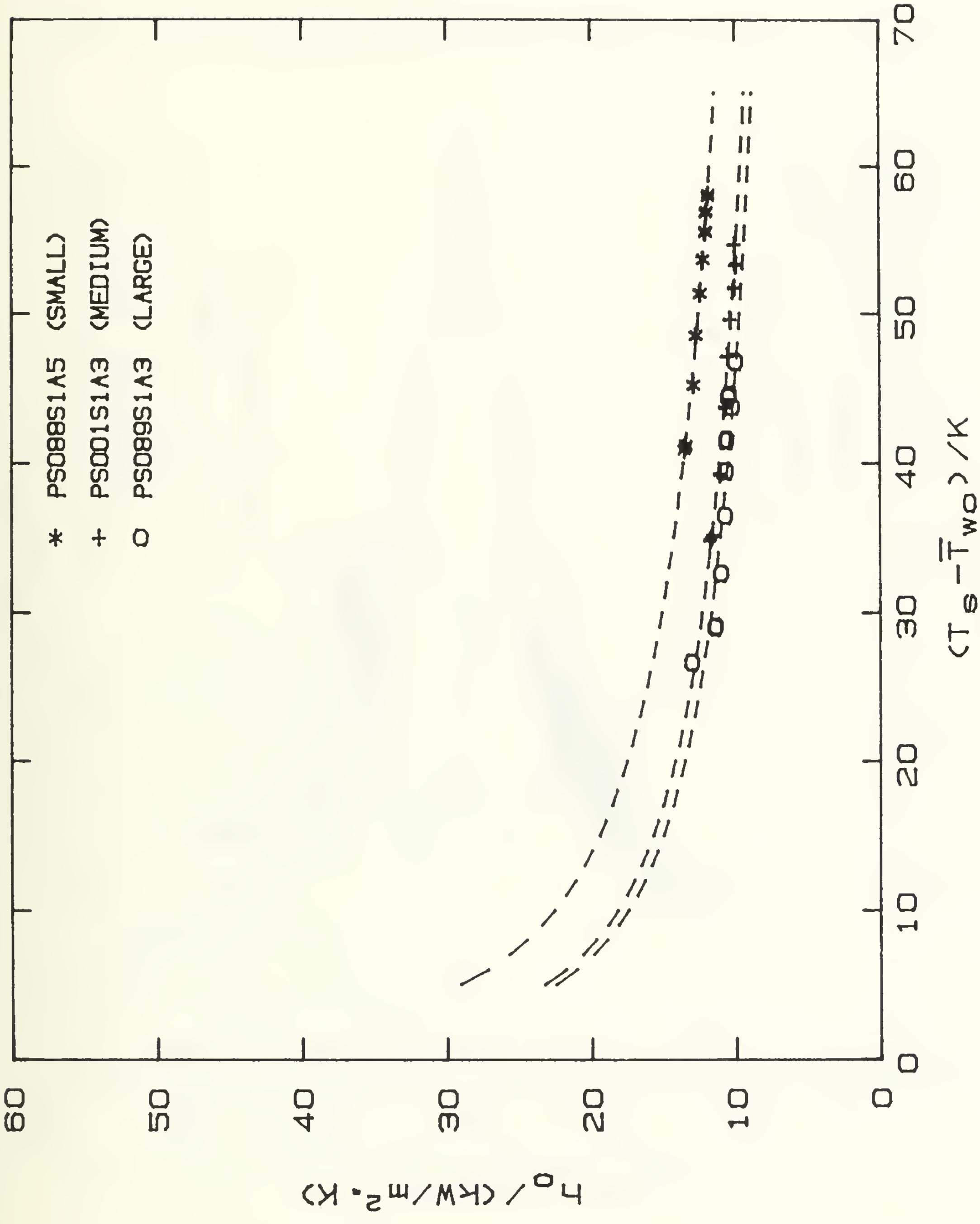

Figure 23. Dependence of Steam Heat Transfer Coefficients on Tube Diameter at Atmospheric Conditions (Smooth Tubes)

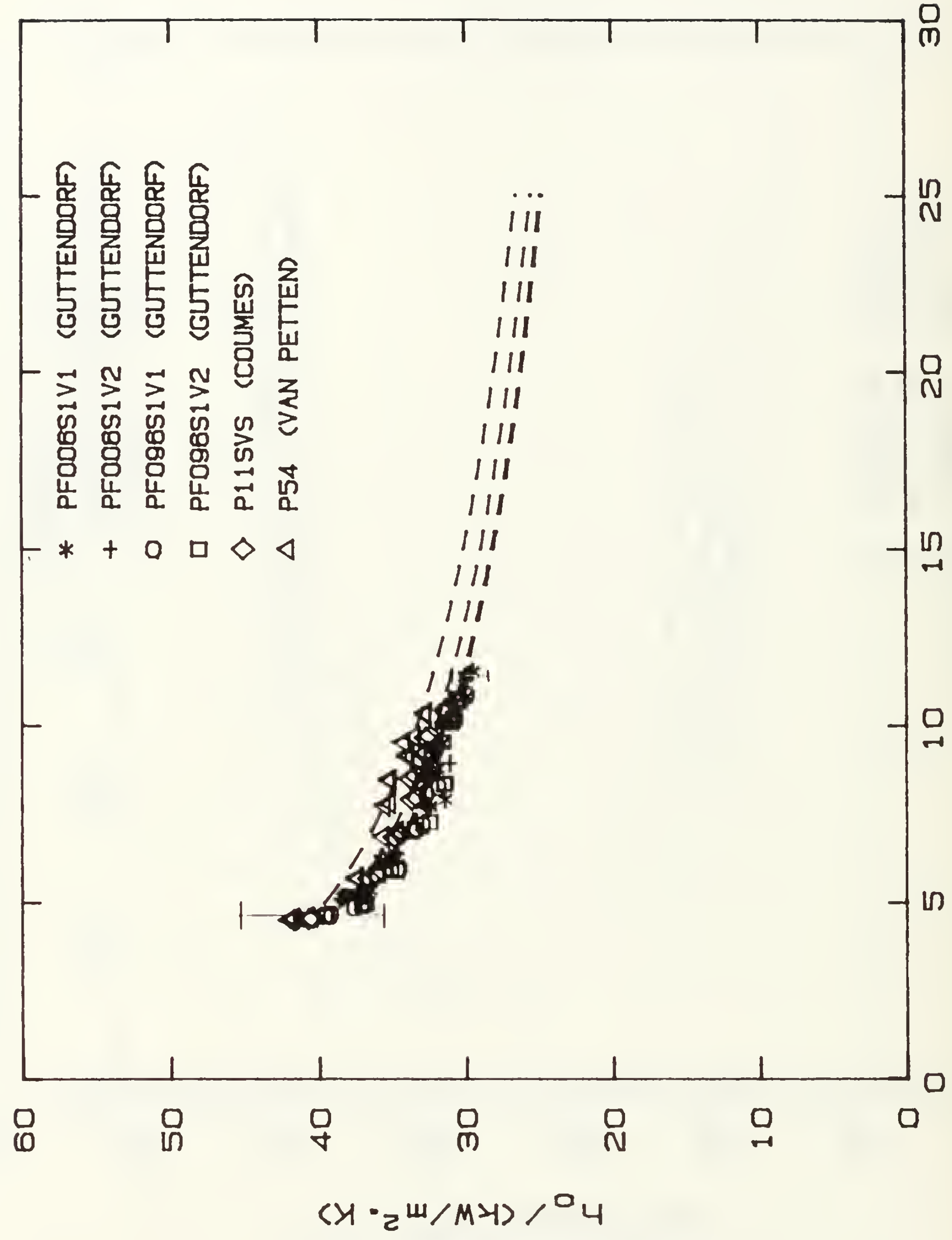

Figure 24. Repeatability of Tubes F006 and F096 at Vacuum Conditions

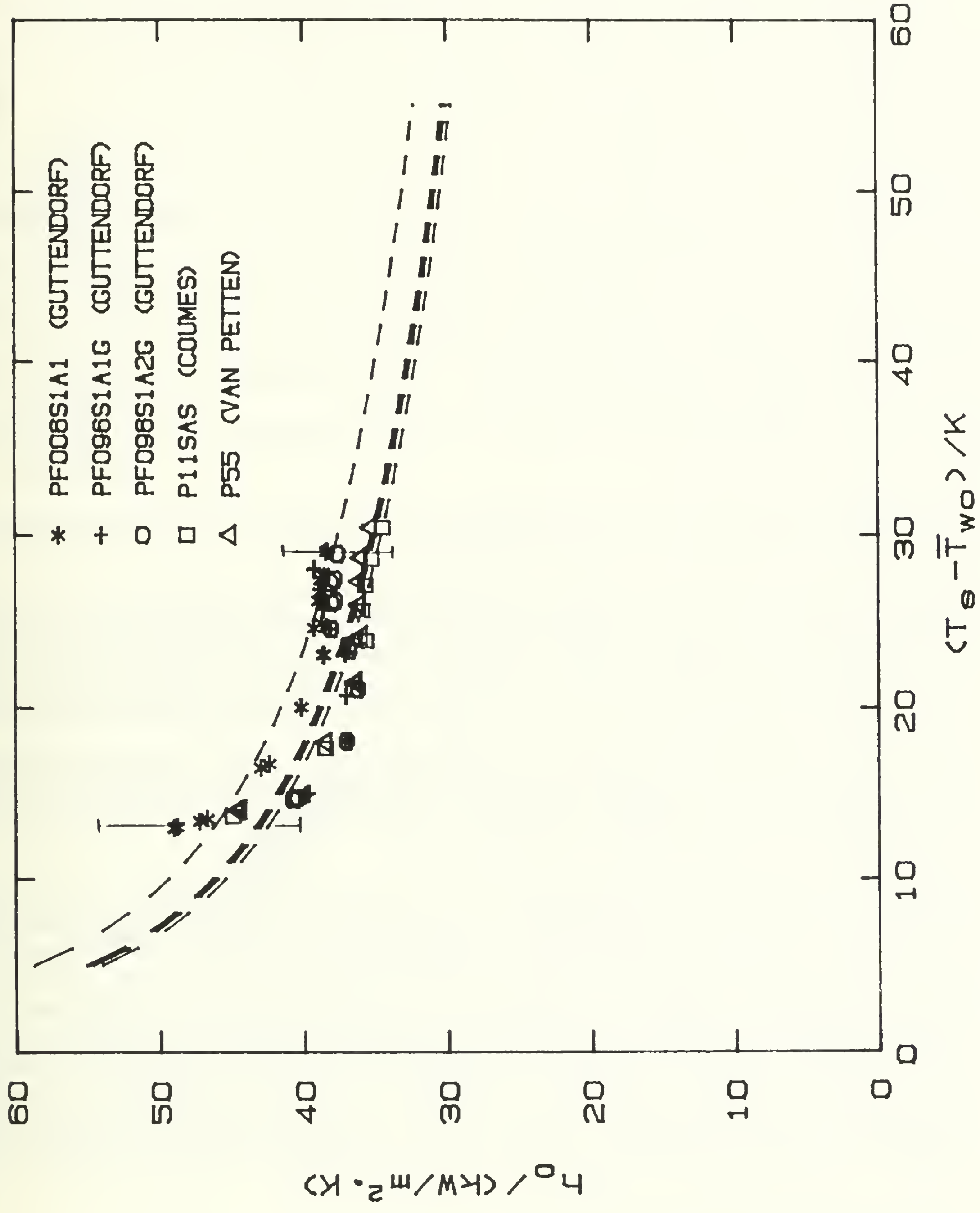

Figure 25. Repeatability of Tubes F006 and F096 at Atmospheric Conditions

biggest discrepancies in the data at the lowest and highest coolant water flow rates. This appears to be the case in Figures 26 and 27.

Figures 28 and 29 are plots of the enhancement ratio (the ratio of the finned tube α to the smooth tube α, see Equation (4.25)) versus fin spacing for the medium and large diameter tubes at vacuum and atmospheric conditions respectively. The curve drawn for the medium tube is an average of the curves obtained by Coumes and Van Petten. These enhancement curves drawn for Coumes and Van Petten's data were obtained by recalculating the enhancement ratios for each fin spacing using the values of α obtained for the medium and large smooth tubes in this investigation instead of those obtained in the previous investigations. This gave a more direct comparison of the data. The points plotted show the results of data taken during this investigation for the 1.5 mm fin spacing medium and large diameter finned tubes. As can be seen, there is good agreement between the current and previous results. Some important points to notice from Figures 28 and 29 are:

> There appears to be an optimum fin spacing of 1.5 mm for the medium and large diameter tubes at both vacuum and atmospheric conditions.
>
> The enhancement ratio for a given tube diameter increases as the vapor pressure increases. The reason for this is that as the vapor pressure increases, the vapor temperature increases and in turn the surface tension decreases resulting in less interfin flooding and more exposed tube surface area. In addition, the condensate viscosity also decreases, thus allowing the condensate to run off through the fins more readily.
>
> The enhancement ratio at a given fin spacing increases as tube root diameter increases. This is because as root diameter increases, the condensate retention angle decreases (see Equation (2.5)), resulting in a thinner condensate film over the unflooded portion of the tube and more exposed surface area. area.
>
> The dip which occurs near a fin spacing of 0.5 mm is a result of the tube being "fully flooded". As the fin spacing decreases, more interfin flooding occurs until the tube is fully flooded. Equation (2.5) predicts a condensate retention angle of 180 degrees for the 0.5 mm fin spacing tube for steam condensation under both vacuum and atmospheric conditions. This is the reason for the gradual decrease in enhancement between 1.5 mm and 0.5 mm. The reason that the enhancement ratio starts to increase again as fin spacing is further decreased is that the low conductivity liquid between the fins is gradually replaced by high conductivity metal. It should be noted that even though these large enhancements at very small fin spacings seem to be acceptable, the percentage increase in surface area that must be added far exceeds the percentage increase in heat-transfer enhancement.

D. SMALL FINNED TUBES

The small finned tube results are now discussed more fully since they were the main focus of this investigation. It was necessary to determine what was happening in the critical region between a fin spacing of 1.0 mm and 2.0 mm. Specifically, why did the

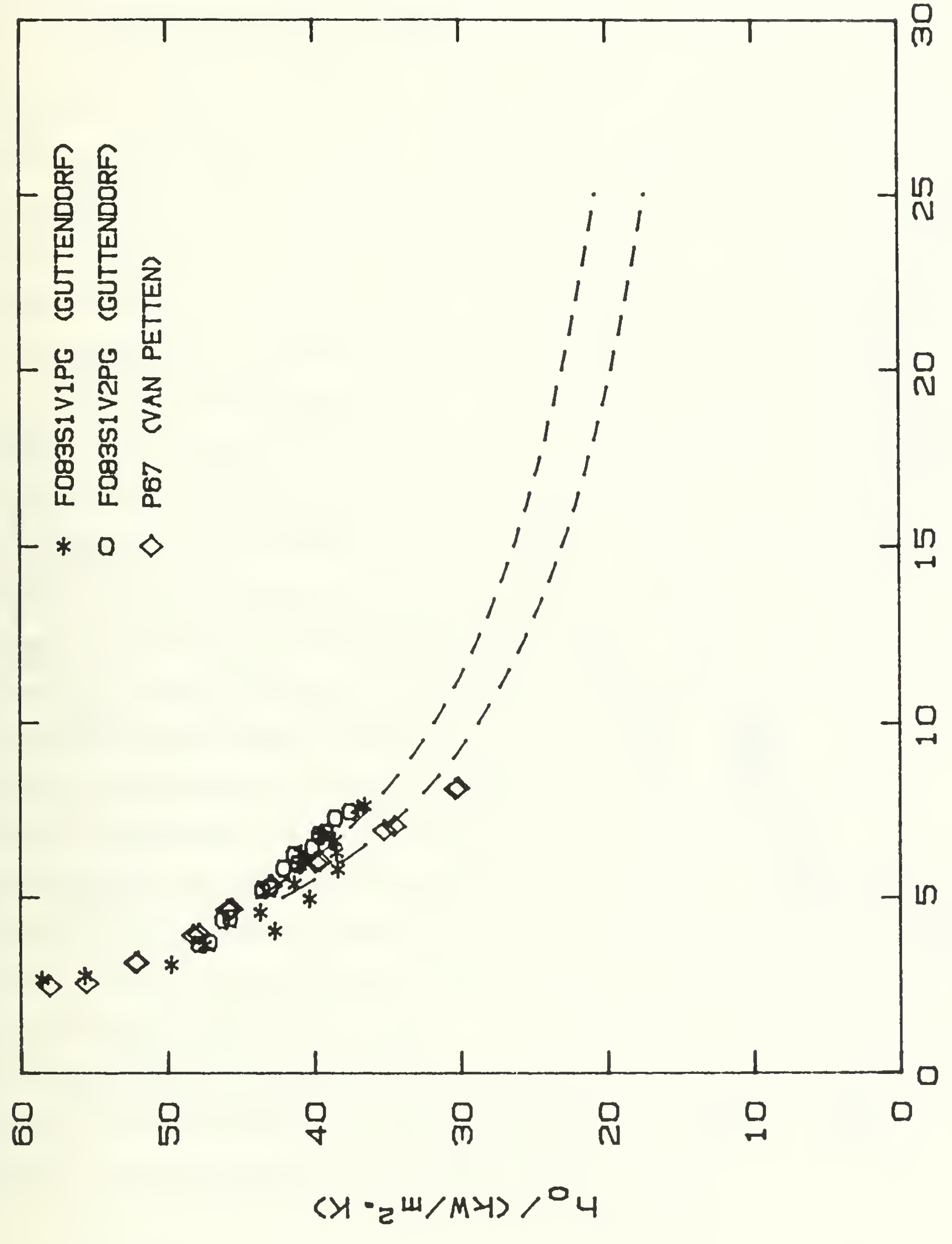

Figure 26. Repeatability of Tube F083 at Vacuum Conditions

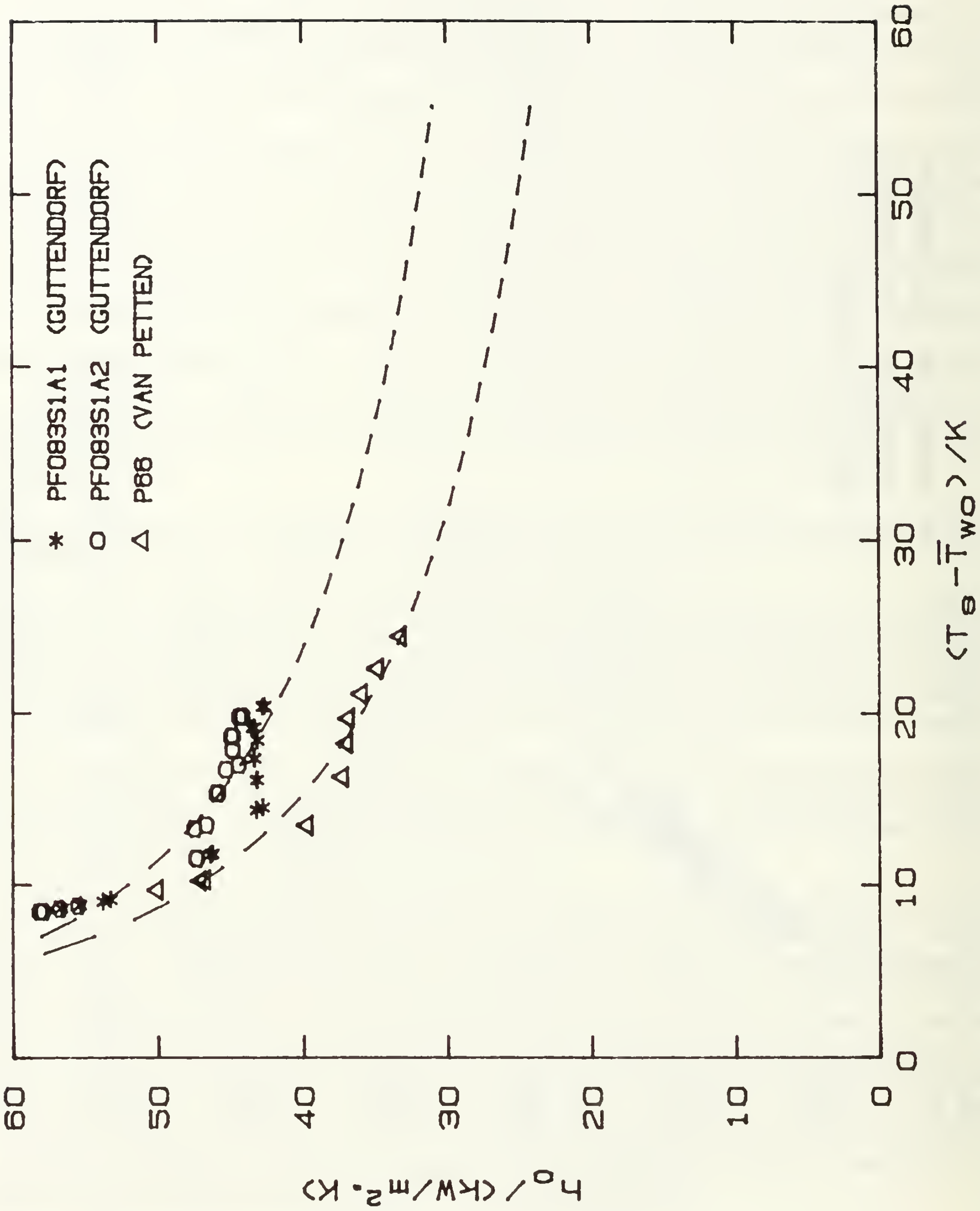

Figure 27. Repeatability of Tube F083 at Atmospheric Conditions

data of Van Petten and Coumes show a dip at a fin spacing of 1.5 mm instead of a peak as would be expected based on the data from the medium and large diameter tubes.

1. Inside Heat-Transfer Coefficient

Table 4 lists the Sieder-Tate leading coefficients (Ci) calculated by the Modified Wilson Plot technique (see Chapter IV section B.2) for all the tubes tested. The Modified Wilson Plot technique computes the Sieder-Tate leading coefficient by using a linear least squares fit to the data and taking the reciprocal of the slope. If the plot of the data did not resemble a straight line, the data was discarded. Figures 30 thru 33 show the Modified Wilson Plot for various tubes (small, medium and large diameters). The X and Y axes are defined in Equations (4.14) and (4.15) respectively. The intercept on the Y axis is $1/\alpha$ as given by Equation (4.17). The value of Ci for tubes with the same internal diameter should be equal. However, looking at Table 4, the Modified Wilson Plot gives slightly different values for different tubes with the same internal diameter. This may be due to the fact that, although the internal diameter is the same for different tubes, the outside boundary conditions varies with both fin spacing and tube root diameter. For the small diameter tubes, the amount of flooding (ie. the condensate retention angle) is different for various fin spacings. For the medium and large diameter tubes (which have the same internal diameter) the difference may be due to the variation in the condensate retention angle based on the tube root diameter. The variation in Ci's is within the expected uncertainty from the Modified Wilson Plot technique. An average value of Ci for the small tubes at both vacuum and atmospheric conditions was determined and these average Ci's were used to determine the outside heat-transfer coefficients for all the small tubes. For the large and medium diameter tubes, the value of Ci used was the value found using the Modified Wilson Plot. The small number of medium and large tubes tested did not permit a representative average to be taken. The average Ci's are listed in Table 5. Notice that the values of Ci generally increase slightly with increasing tube diameter and decrease slightly with increasing vapor pressure.

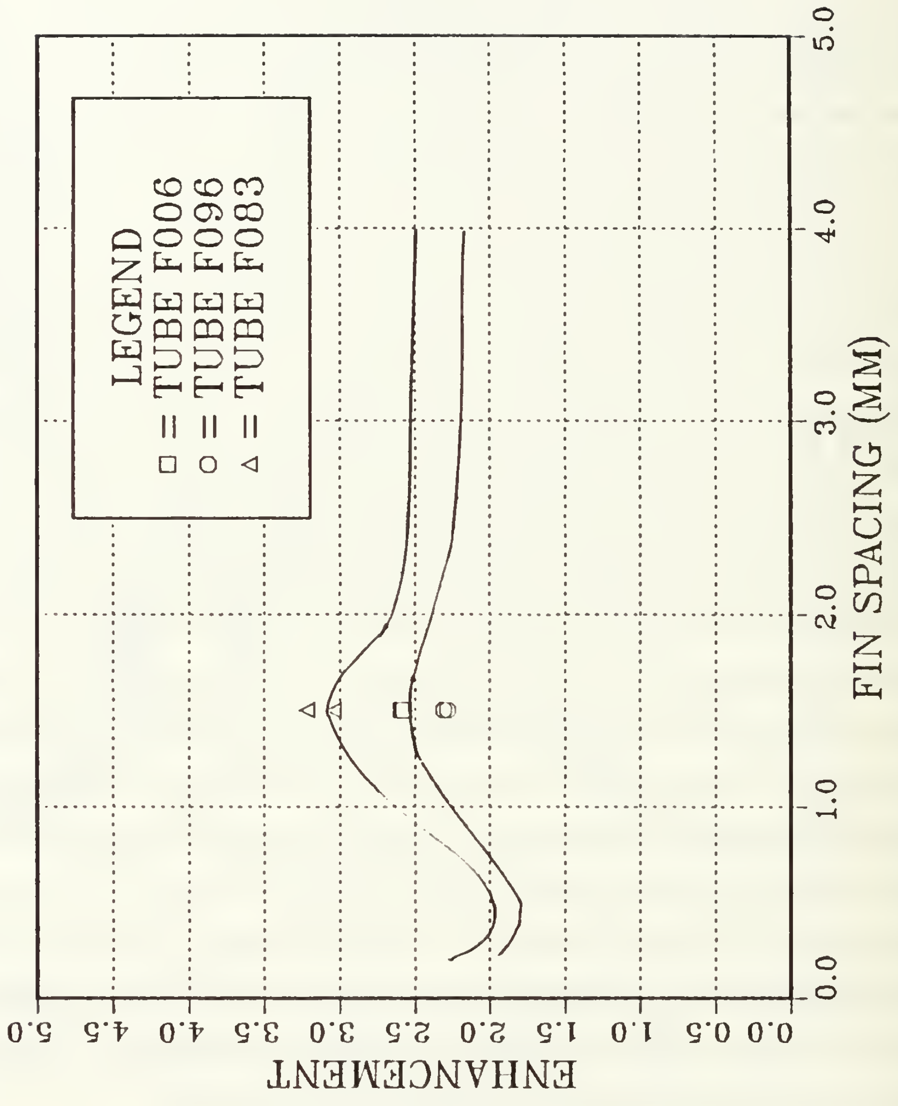

Figure 28. Enhancements for Medium and Large Diameter Tubes (Vacuum) Showing Present Investigation Results

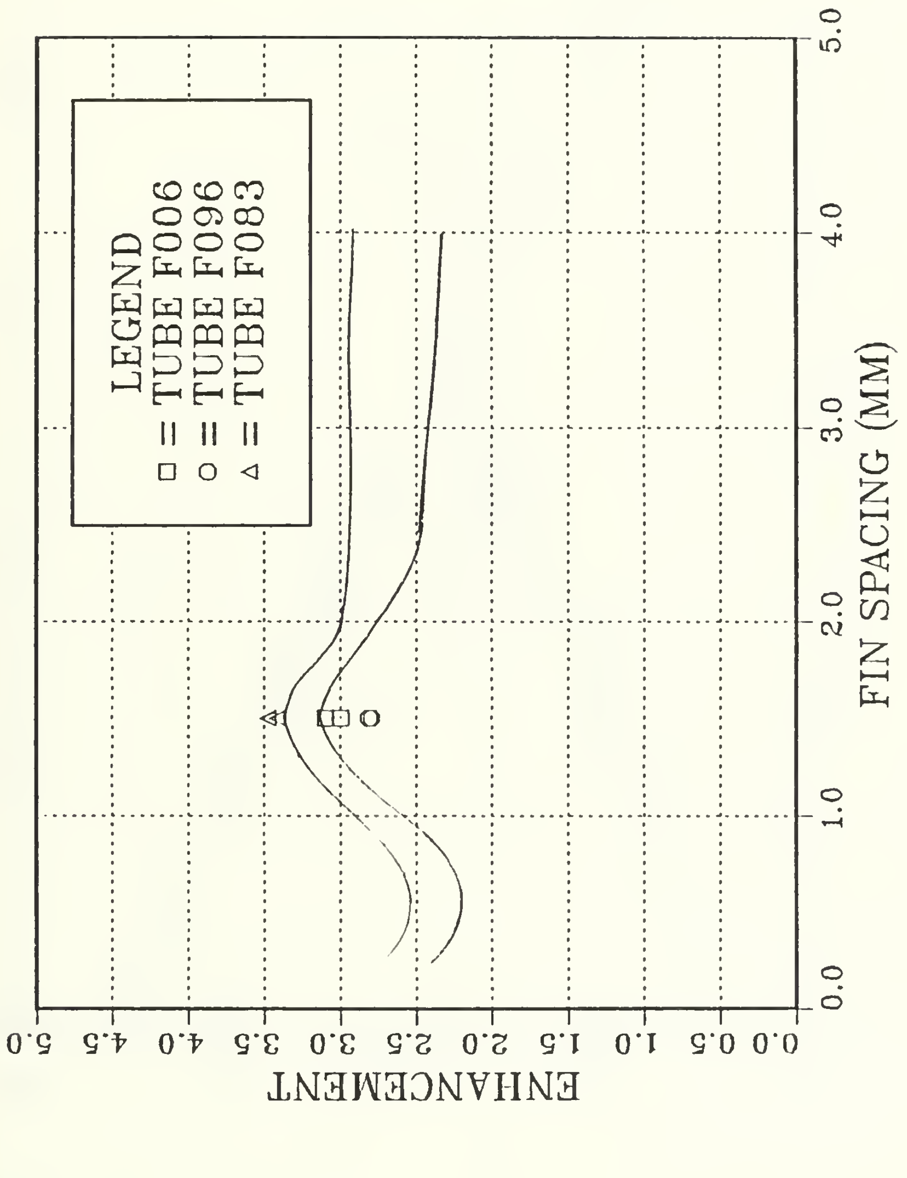

Figure 29. Enhancements for Medium and Large Diameter Tubes (Atmospheric) Showing Present Investigation Results

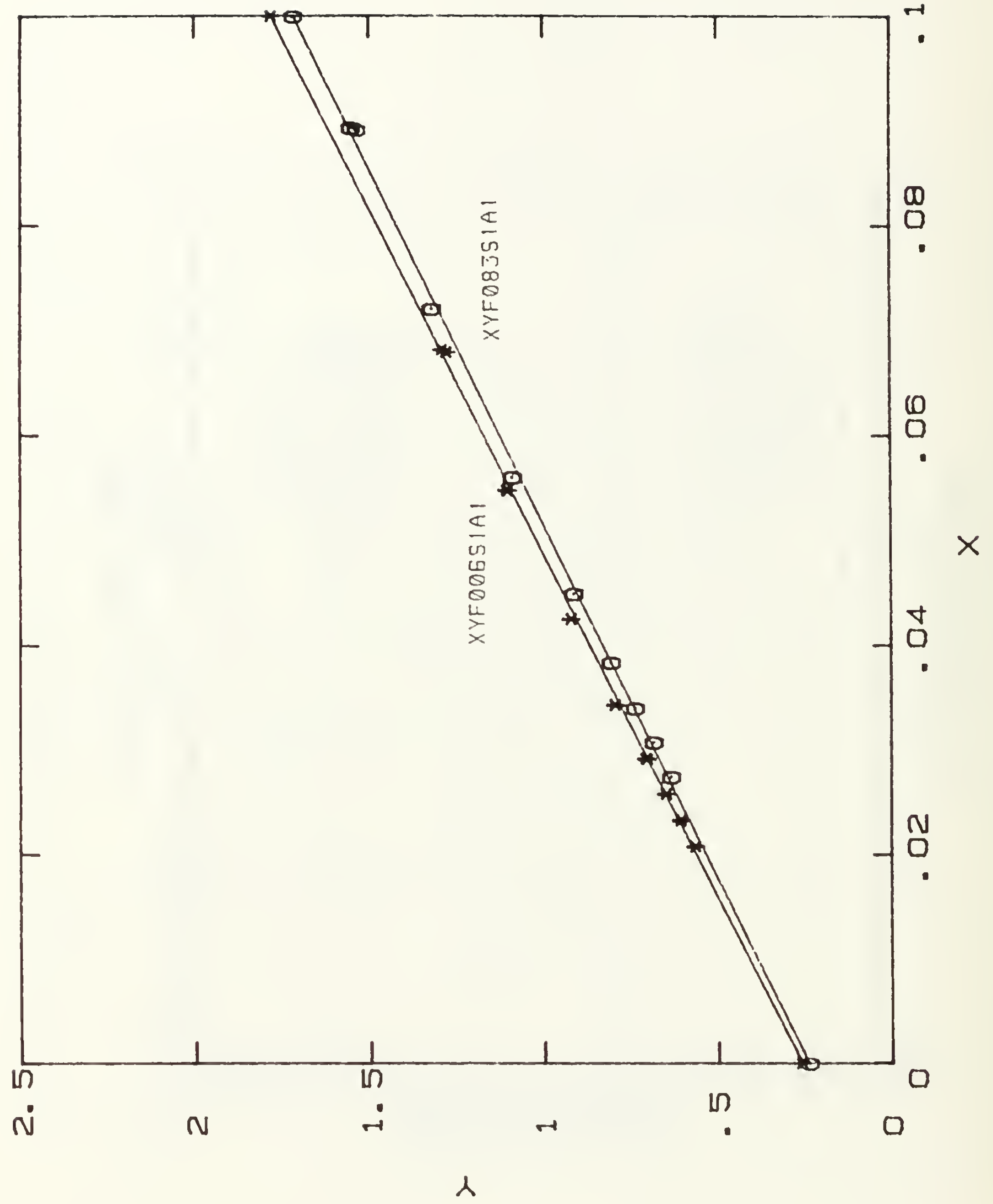

Figure 30. Modified Wilson Plot for Tubes F006 and F083 at Atmospheric Conditions (insert)

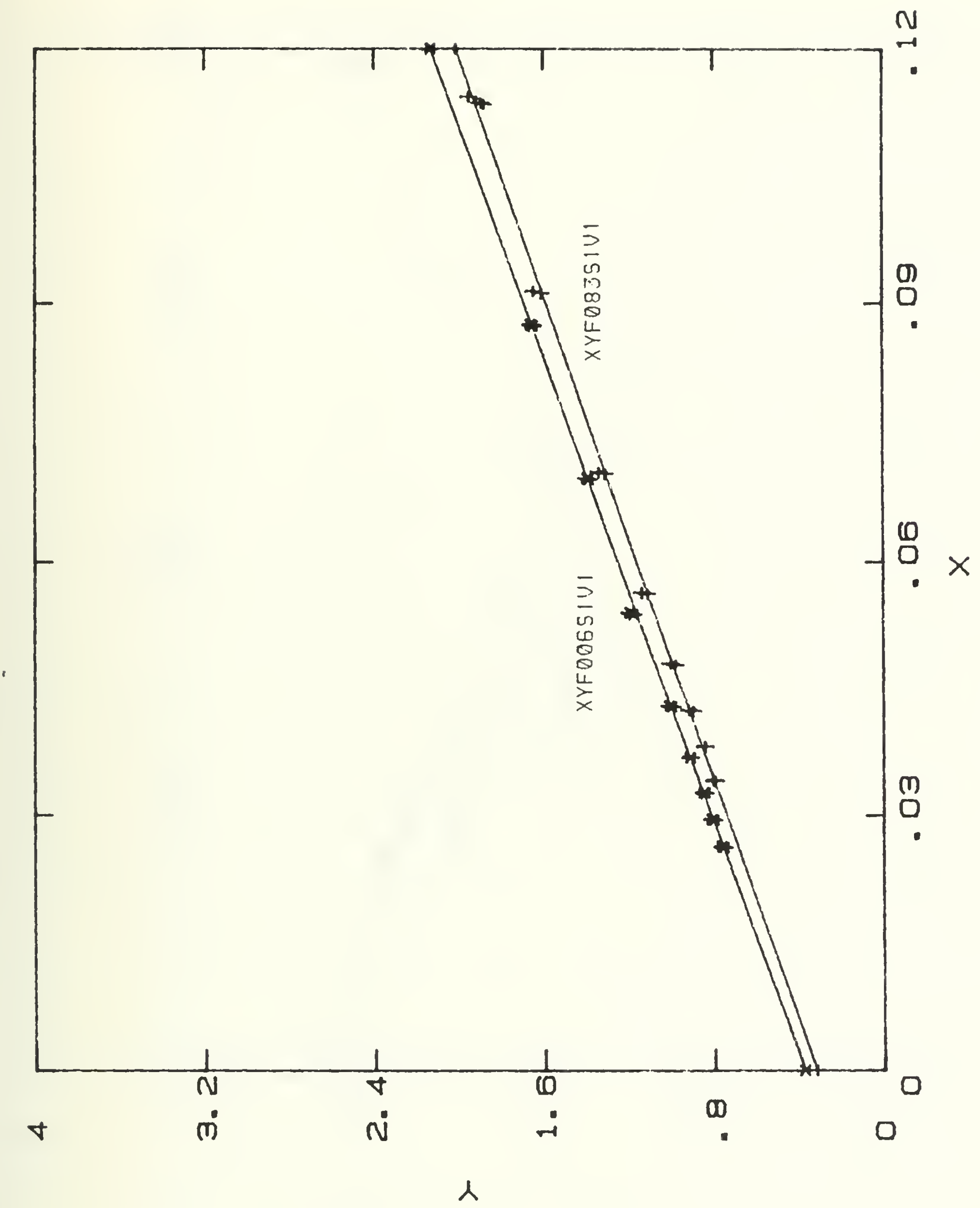

Figure 31. Modified Wilson Plot for Tubes F006 and F083 at Vacuum Conditions (insert)

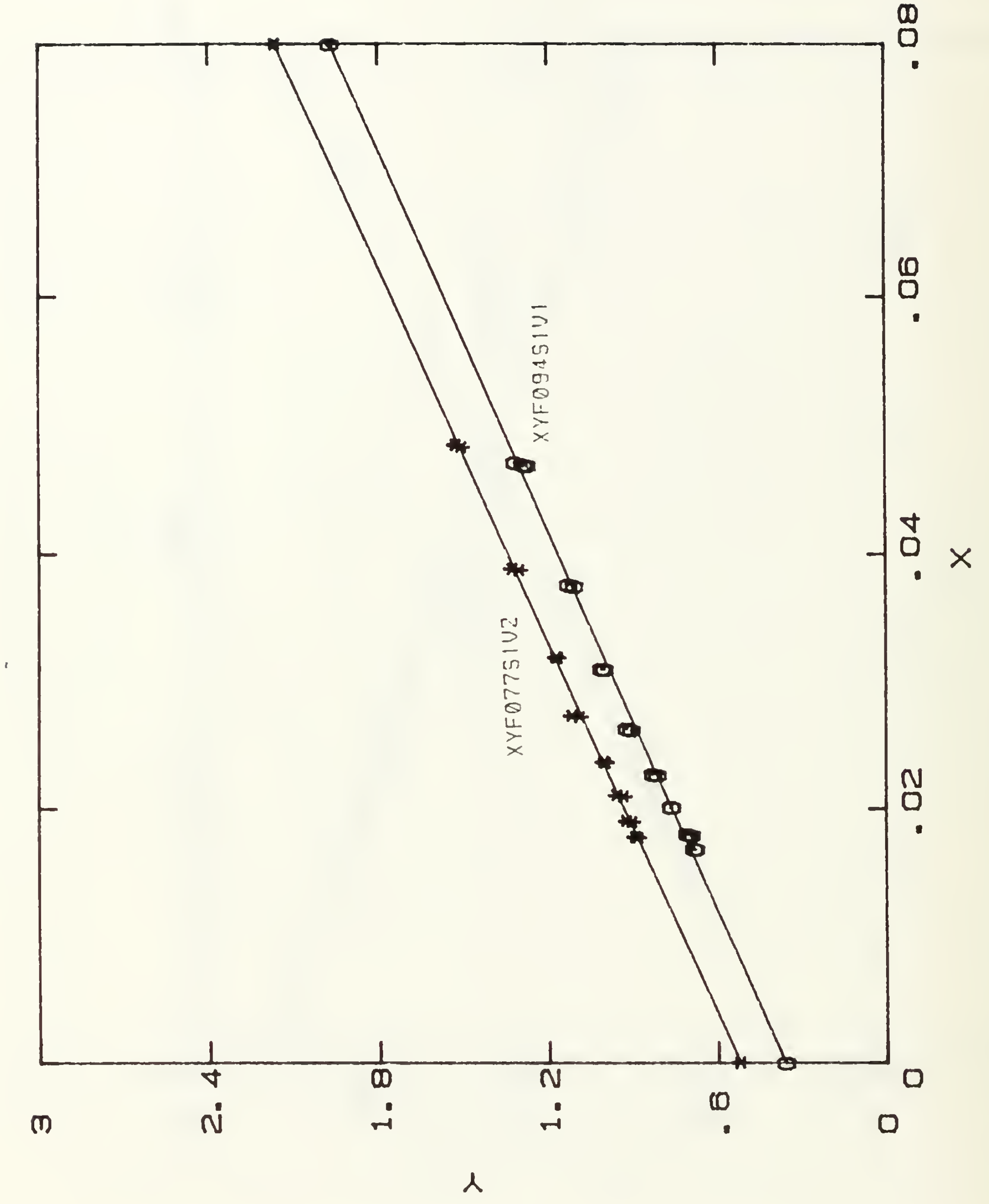

Figure 32. Modified Wilson Plot for Tubes F077 and F094 at Vacuum Conditions (insert)

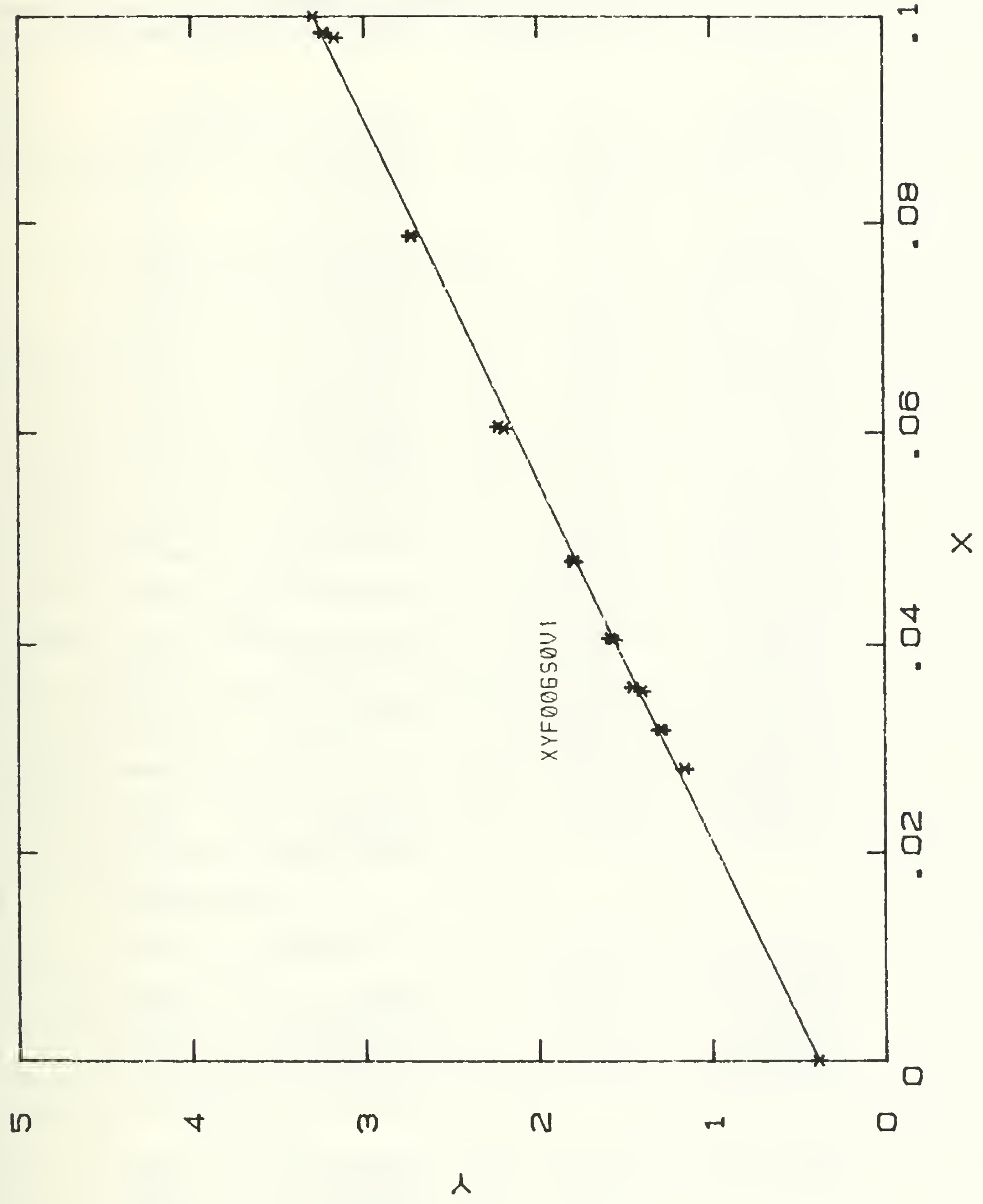

Figure 33. Modified Wilson Plot for Tube F006 at Vacuum Conditions (no insert)

Table 4. SIEDER-TATE COEFFICIENTS (WITH INSERT)

Tube	File Name	Vacuum	File Name	Atmospheric
Small Tubes				
S088	S088S1V3	.050	S088S1A5	.051
F074	F074S1V1	.055	F074S1A1	.052
	F074S1V2	.051	F074S1A2	.052
F075	F075S1V1	.054	F075S1A1	.049
	F075S1V2	.055	F075S1A2	.049
F076	F076S1V1	.054	F076S1A1	.047
	F076S1V2	.051	F076S1A2	.049
F077	F077S1V1	.049	F077S1A1	.045
	F077S1V2	.049	F077S1A2	.045
F078	F078S1V1	.049	F078S1A1	.048
	F078S1V2	.049	F078S1A2	.047
			F078S1A3	.047
F079	F079S1V1	.052	F079S1A1	.047
F090	F090S1V1	.051	F090S1A1	.047
	F090S1V2	.051		
F091	F091S1V1	.056	F091S1A1	.046
	F091S1V2	.054		
F092	F092S1V1	.049	F092S1A1	.045
	F092S1V2	.053		
F093	F093S1V1	.053	F093S1A1	.048
	F093S1V2	.051		
F094	F094S1V1	.050	F094S1A1	.048
	F094S1V2	.048		
F095	F095S1V1	.048	F095S1A1	.048
	F095S1V2	.049		
F086	F086S1V1	.049	F086S1A1	.047
(QMCNPS)			F086S1A2	.048
Medium Tubes				
S001	S001S1V3	.067	S001S1A3	.068
	S001S1V4	.069		
F006	F006S1V1	.068	F006S1A1	.066
	F006S1V2	.069	F006S1A2	.065
F096	F096S1V1	.063	F096S1A1	.058
	F096S1V2	.063	F096S1A2	.059
Large Tubes				
S089	S089S1V2	.065	S089S1A3	.065
	S089S1V3	.065	S089S1A4	.061
			S089S1A5	.067
F083	F083S1V1	.071	F083S1A1	.068
	F083S1V2	.074	F083S1A2	.067

Table 5. AVERAGE SIEDER-TATE COEFFICIENTS (WITH INSERT)

Diameter	Vacuum	Atmospheric
Small	.051	.048
Medium	.067	.063
Large	.069	.066

2. Outside Heat-Transfer Coefficient

The outside heat-transfer coefficient was calculated using Equation (4.18). Figures 34 thru 46 show the repeatability of the outside heat-transfer coefficient for the small diameter tubes. As stated previously, a new small family of tubes was manufactured. Four of the tubes in this new small family (F090, F091, F092 and F094) exactly matched four tubes from the old small family (F074, F075, F076 and F077). Tubes F077 and F094 were the 1.5 mm fin spacing tubes and, consequently, of the most interest due to the discrepancies discussed earlier. As can be seen in Figures 38 and 43, data taken for tube F077 compares well with that taken in the past. Data taken for tube F094, however, shows considerable difference; it shows a higher outside heat-transfer coefficient than the old tube, F077. This difference led to doubts about the old small 1.5 mm fin spacing results. Also, tubes F093 (1.25 mm fin spacing) and F095 (1.75 mm fin spacing) show outside heat-transfer coefficients which compare better with tube F094 (new) than F077 (old), casting more doubt on tube F077 results. All of the results shown in the figures for Van Petten and Coumes are calculated using their values of Ci.

3. Enhancement Ratios

Figures 45 and 46 show the enhancement ratios for all the small finned tubes, old and new, at vacuum and atmospheric conditions respectively. Figure 45 shows that, at vacuum conditions, the enhancement ratios for all three investigators agree very well except for a fin spacing of 1.5 mm. Here, an increase in enhancement for the new small tube with a fin spacing of 1.5 mm is indicated. The similar enhancement ratios seen for the 1.25 and 1.75 mm fin spacing tubes tend to reinforce this. In Figure 46 , at atmospheric conditions, the results for all three investigators are not in as good agreement as for vacuum conditions. However, the new small tubes with fin spacings of 1.25, 1.5 and 1.75 mm again suggest a small peak in enhancement as opposed to a small dip as indicated by the old small tube family. The reason for this difference is not known. The old small tube with a fin spacing of 1.5 mm needs to be looked at in more detail (a mi-

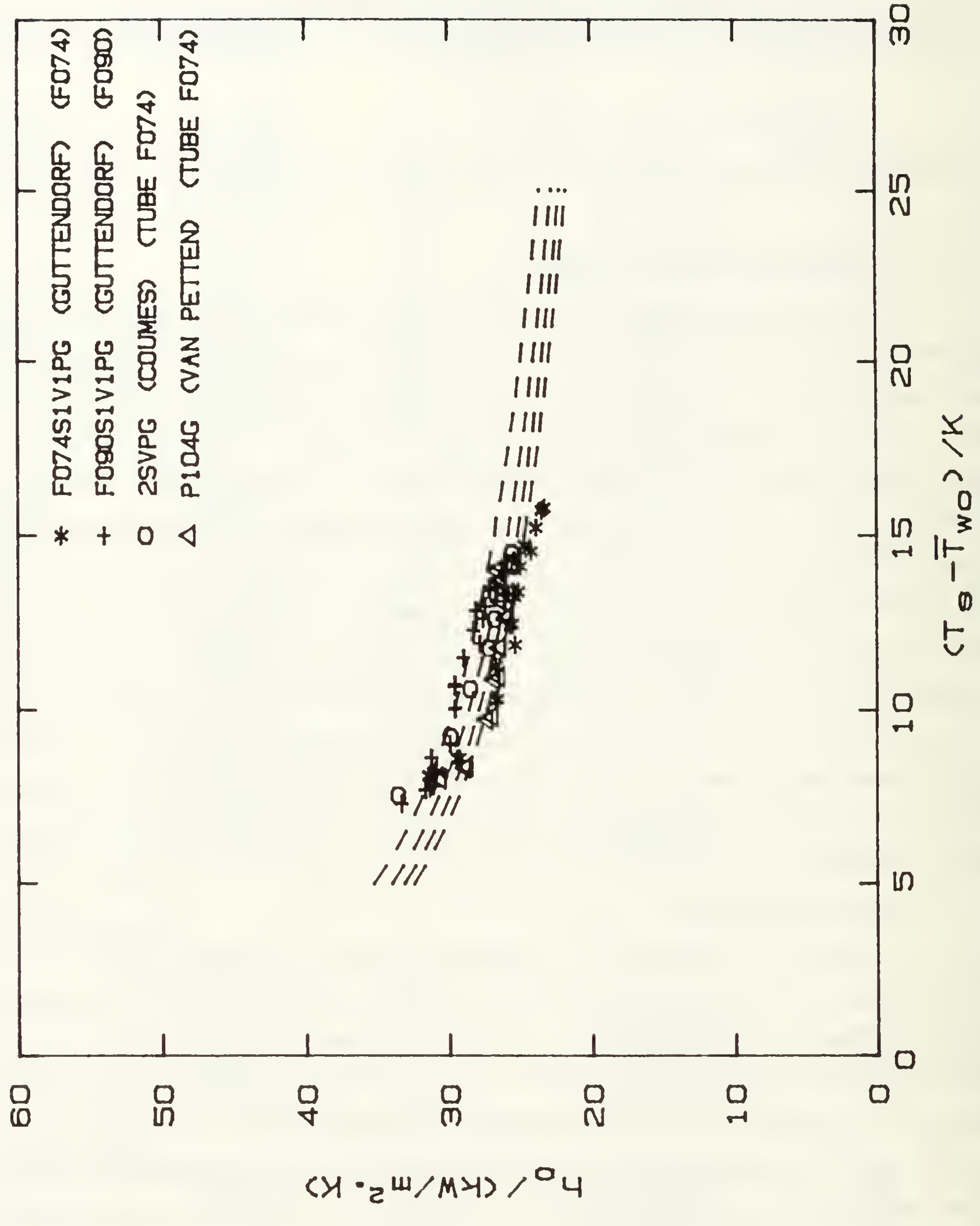

Figure 34. Repeatability of Tubes F074 and F090 (Vacuum)

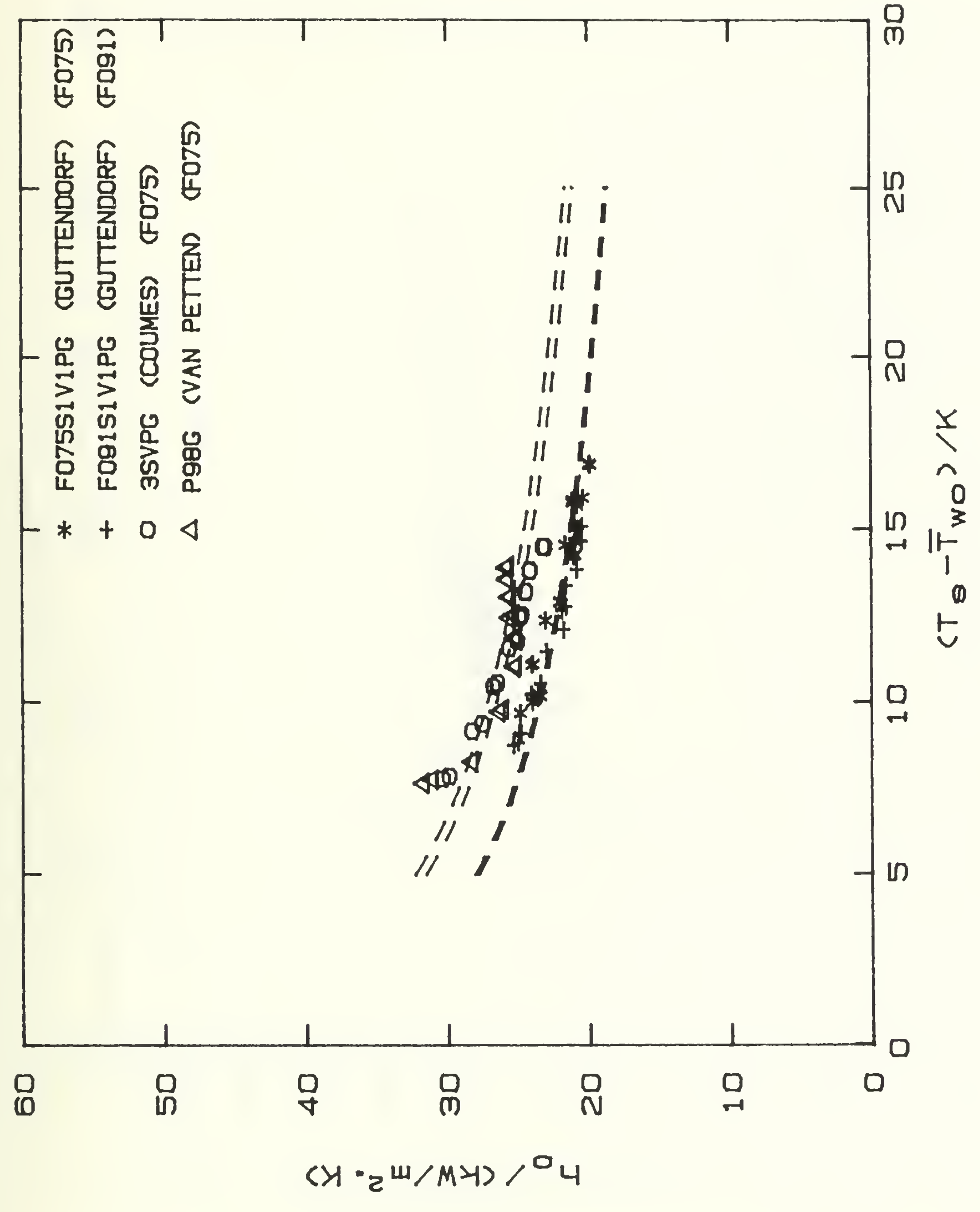

Figure 35. Repeatability of Tubes F075 and F091 (Vacuum)

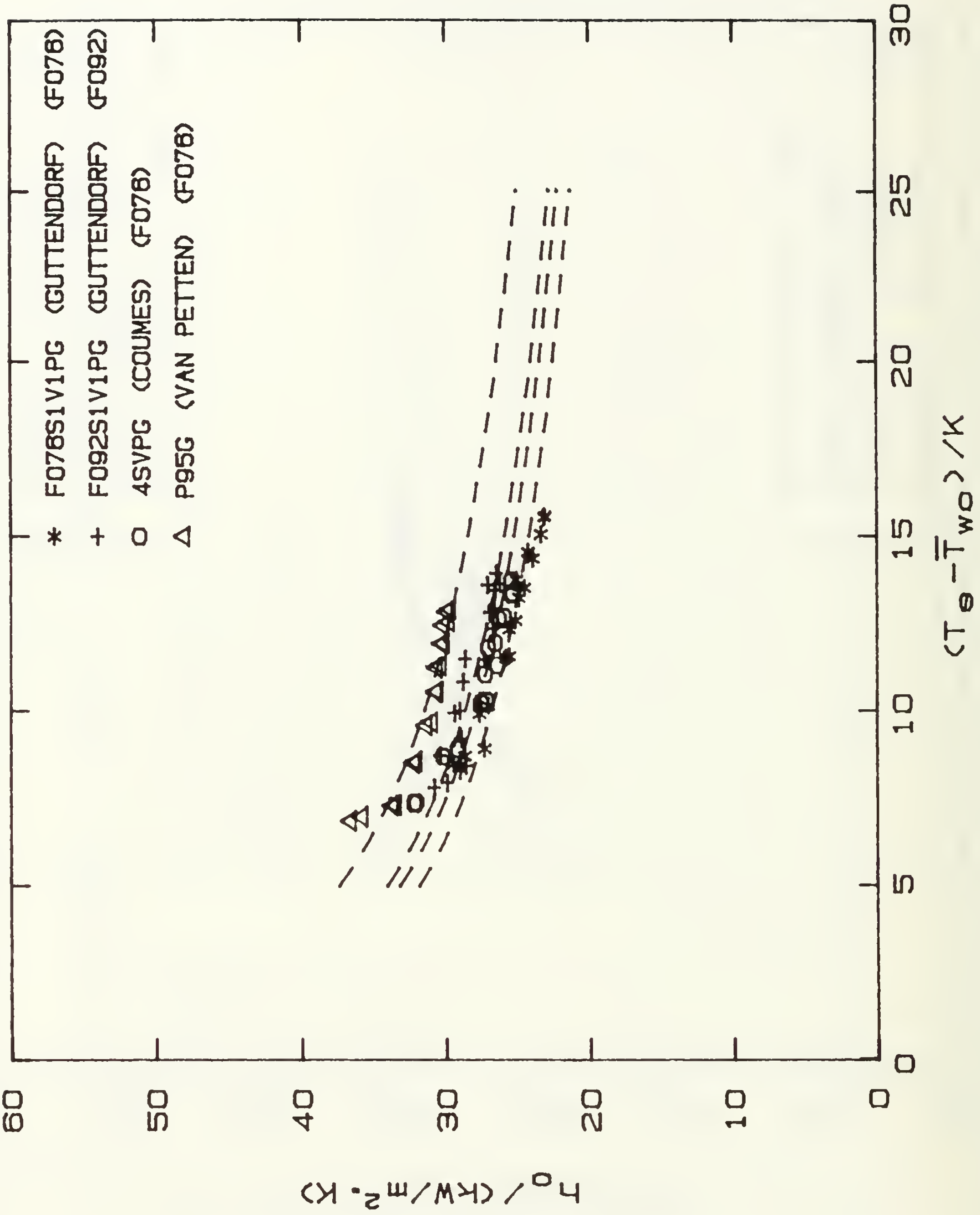

Figure 36. Repeatability of Tubes F076 and F092 (Vacuum)

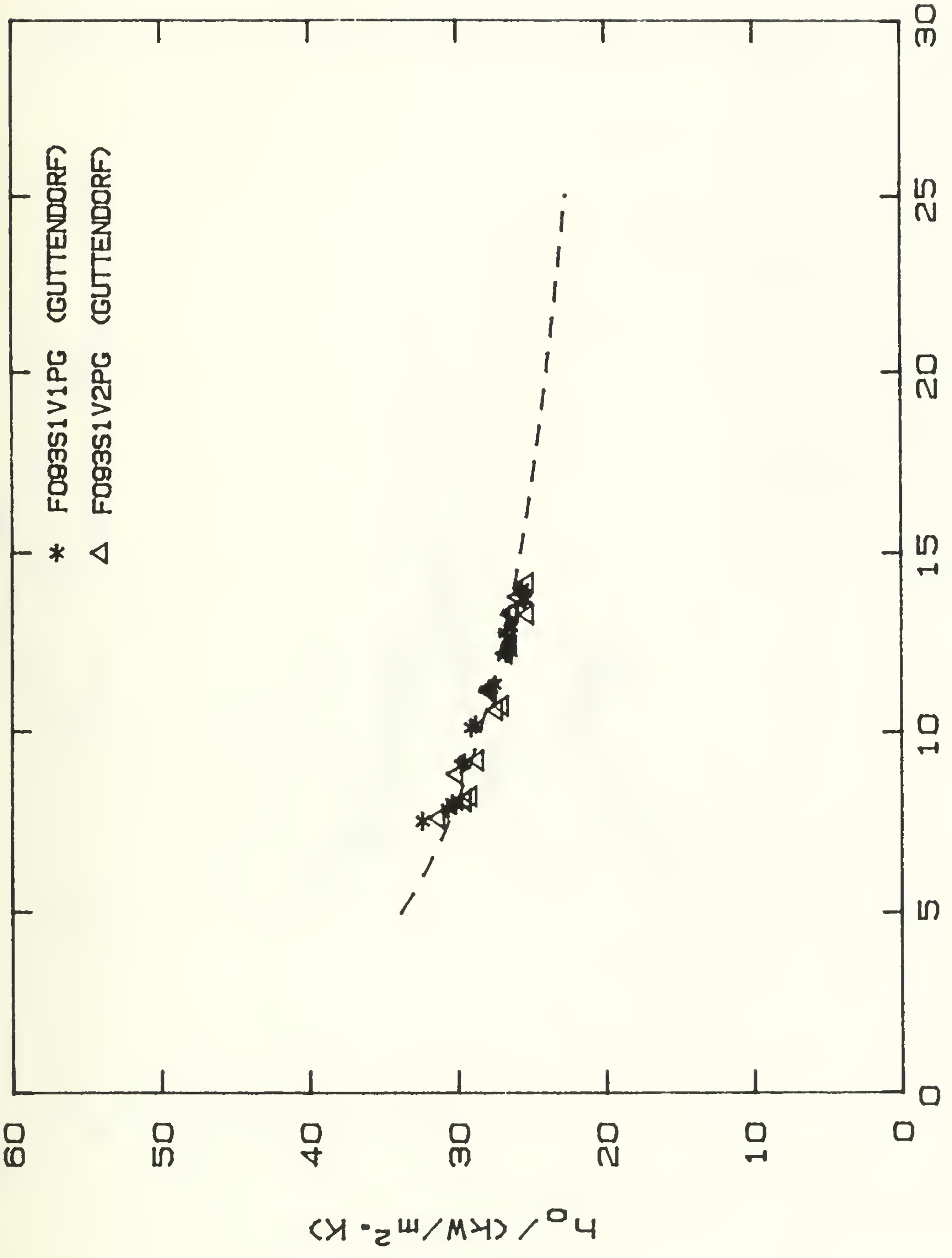

Figure 37. Repeatability of Tube F093 (Vacuum)

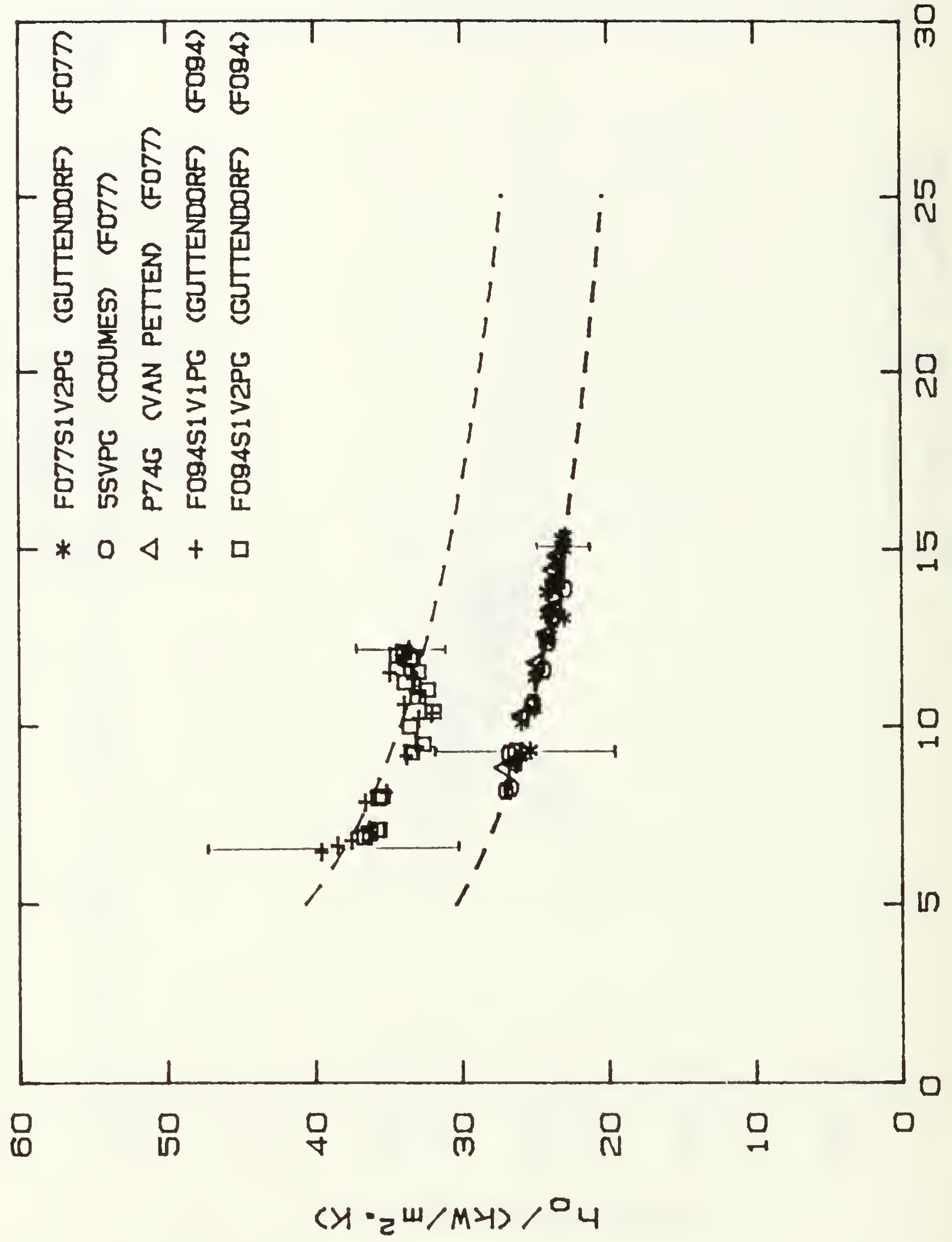

Figure 38. Repeatability of Tubes F077 and F094 (Vacuum)

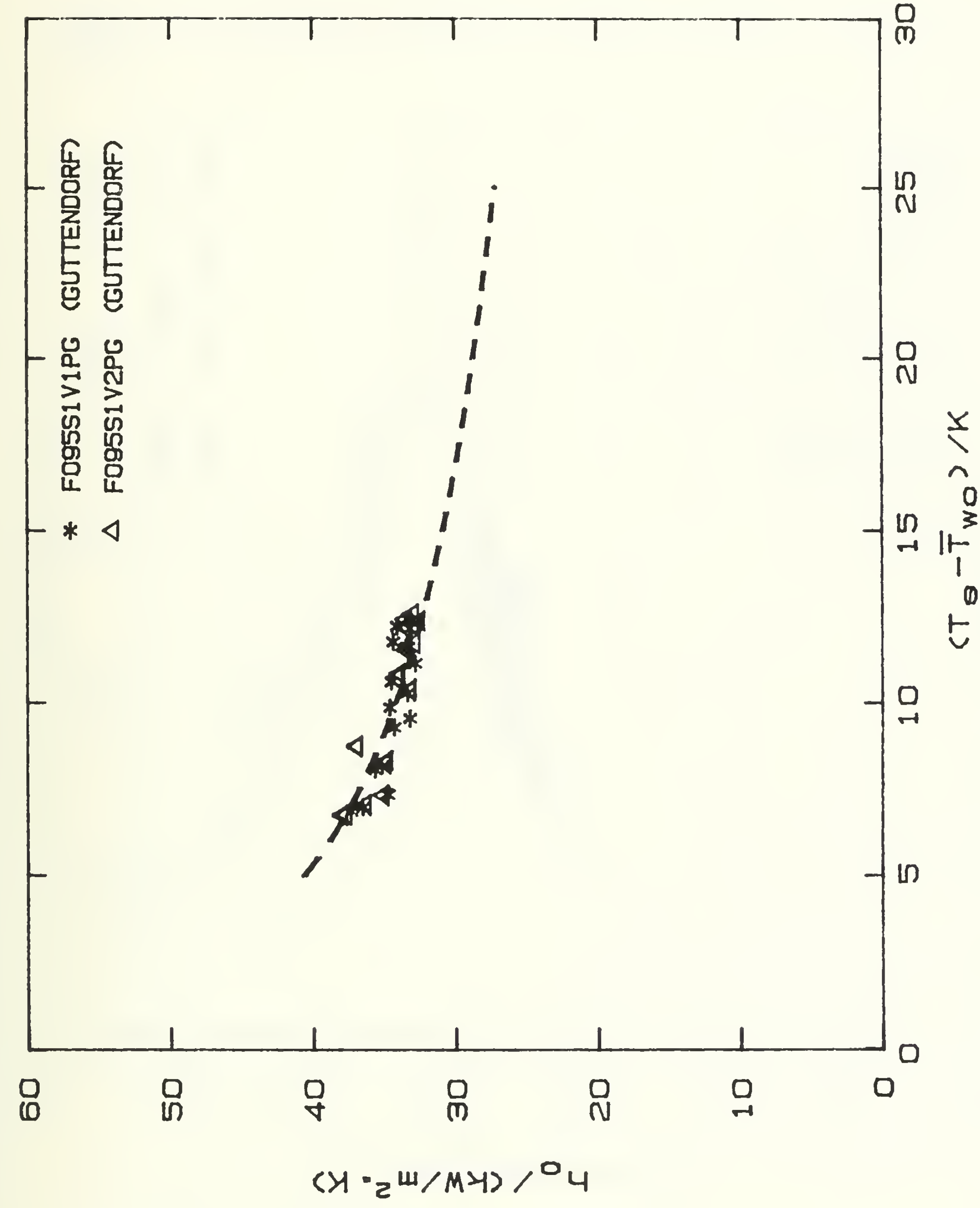

Figure 39. Repeatability of Tube F095 (Vacuum)

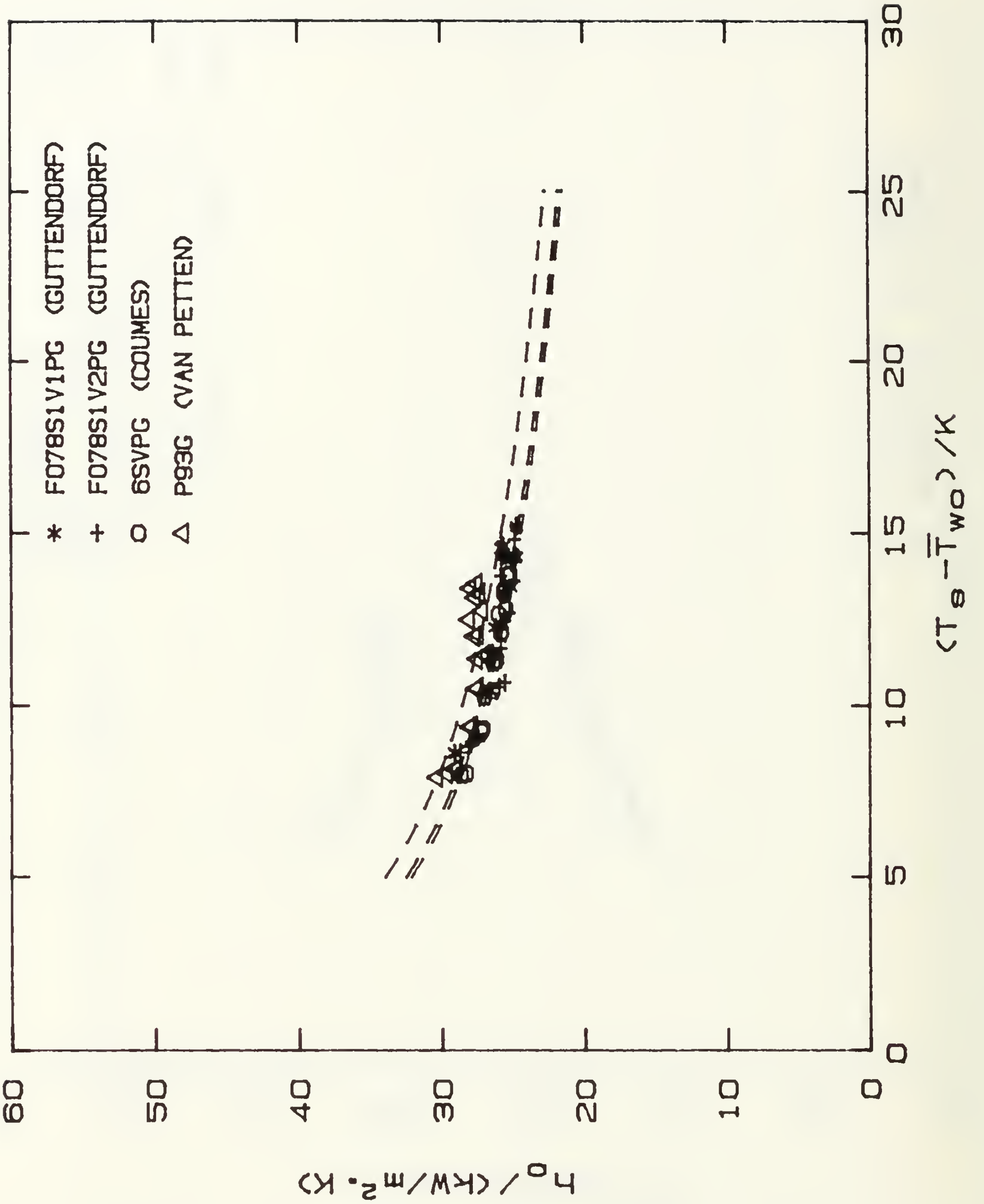

Figure 40. Repeatability of Tube F078 (Vacuum)

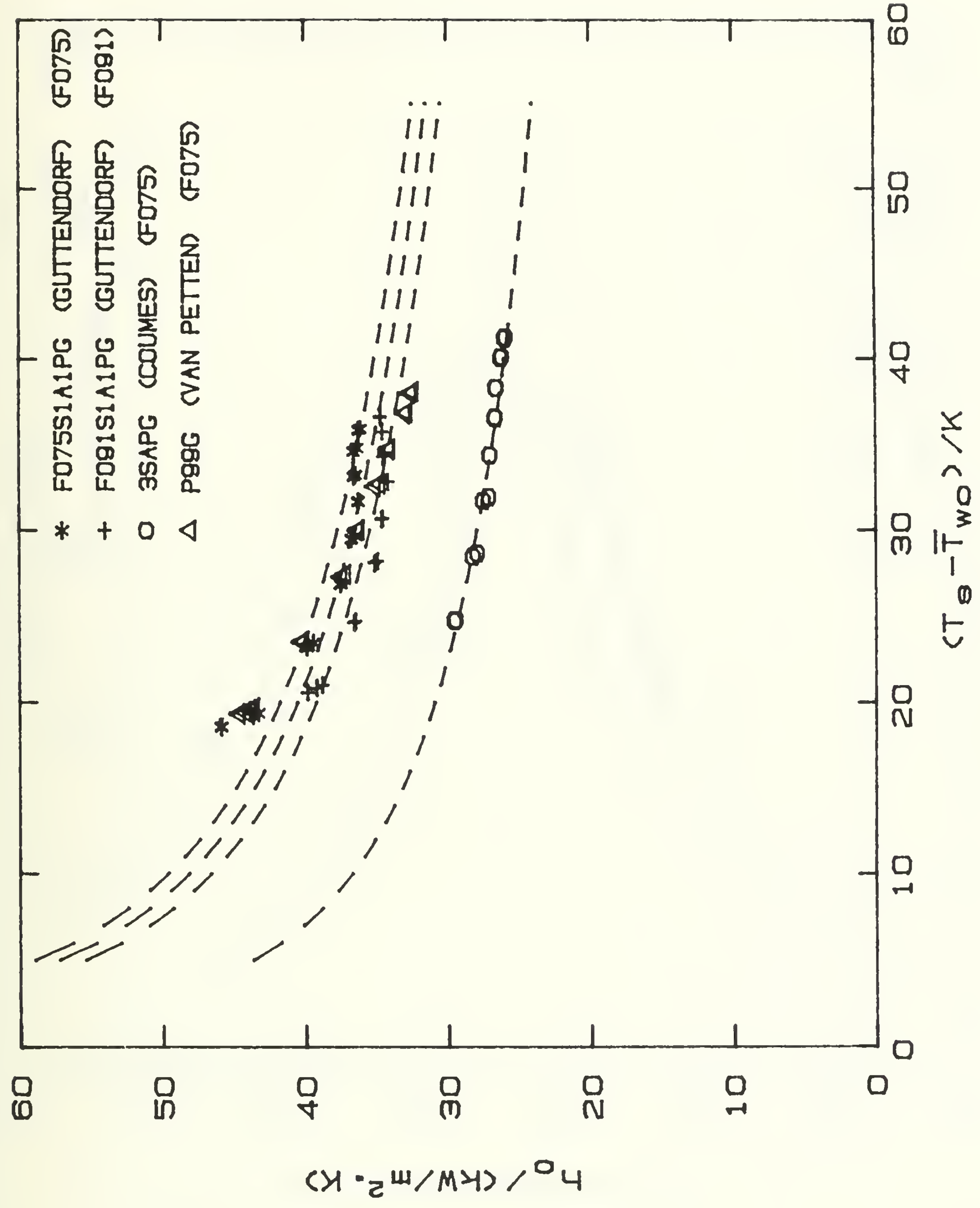

Figure 41. Repeatability of Tubes F075 and F091 (Atmospheric)

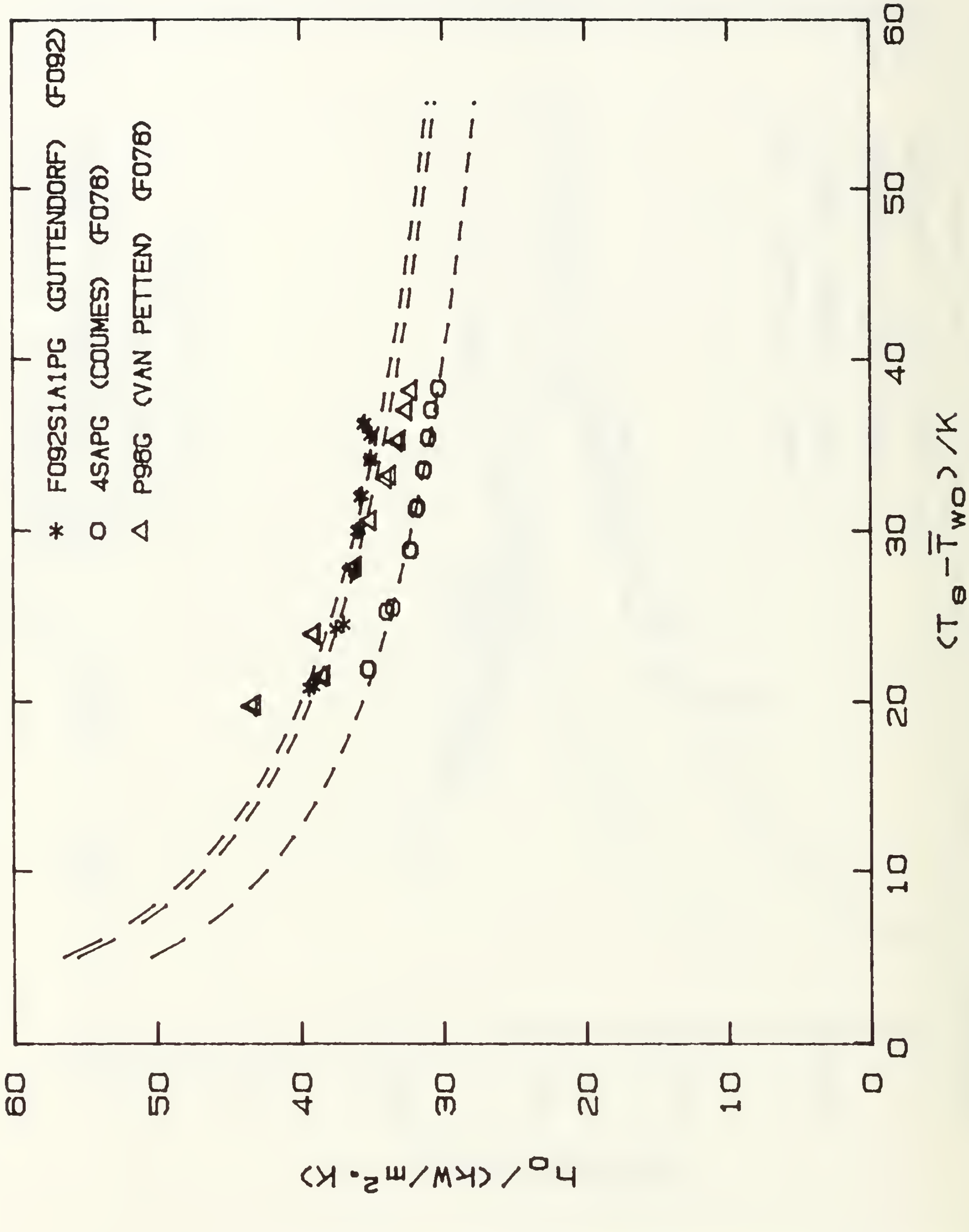

Figure 42. Repeatability of Tubes F076 and F092 (Atmospheric)

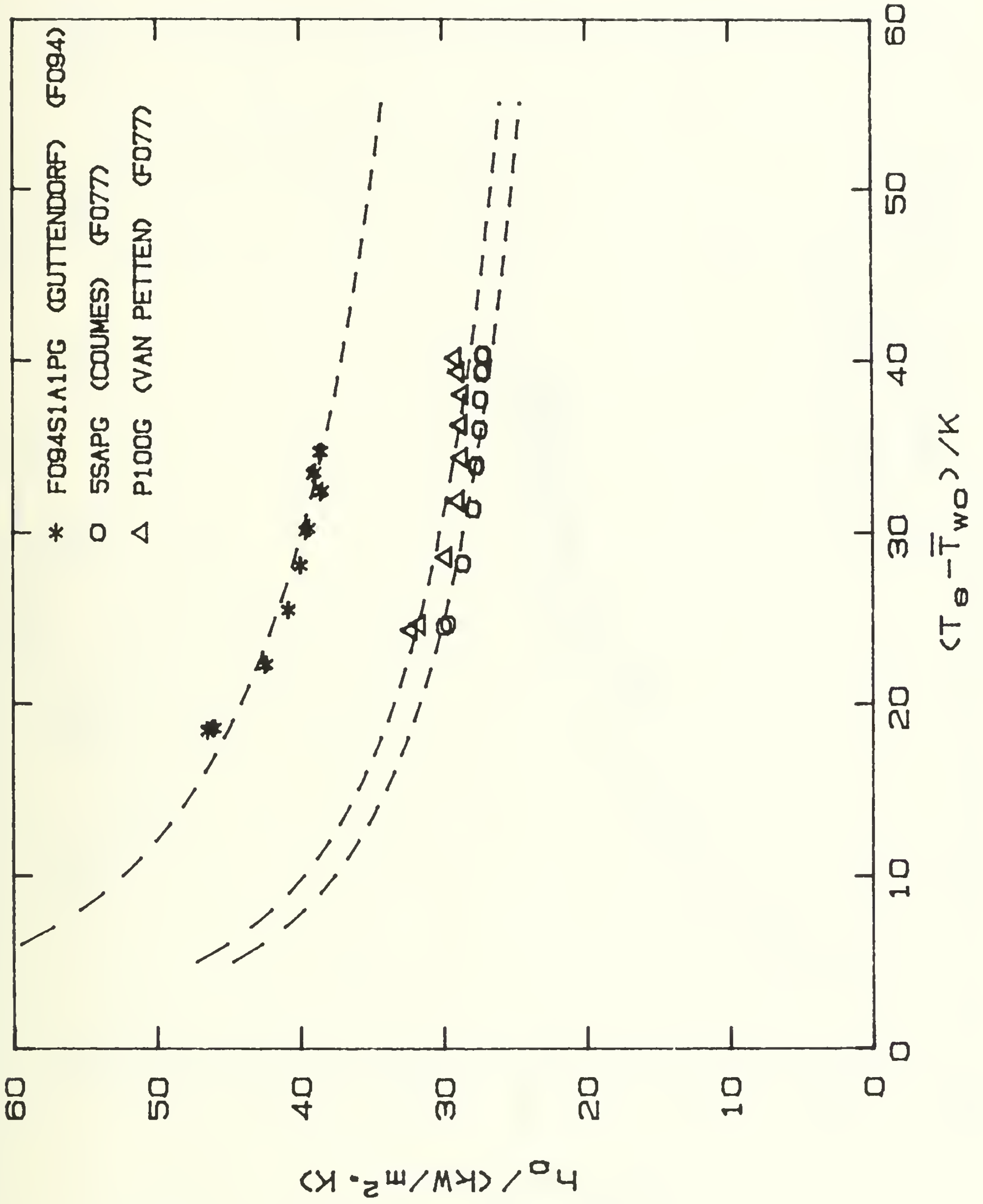

Figure 43. Repeatability of Tubes F077 and F094 (Atmospheric)

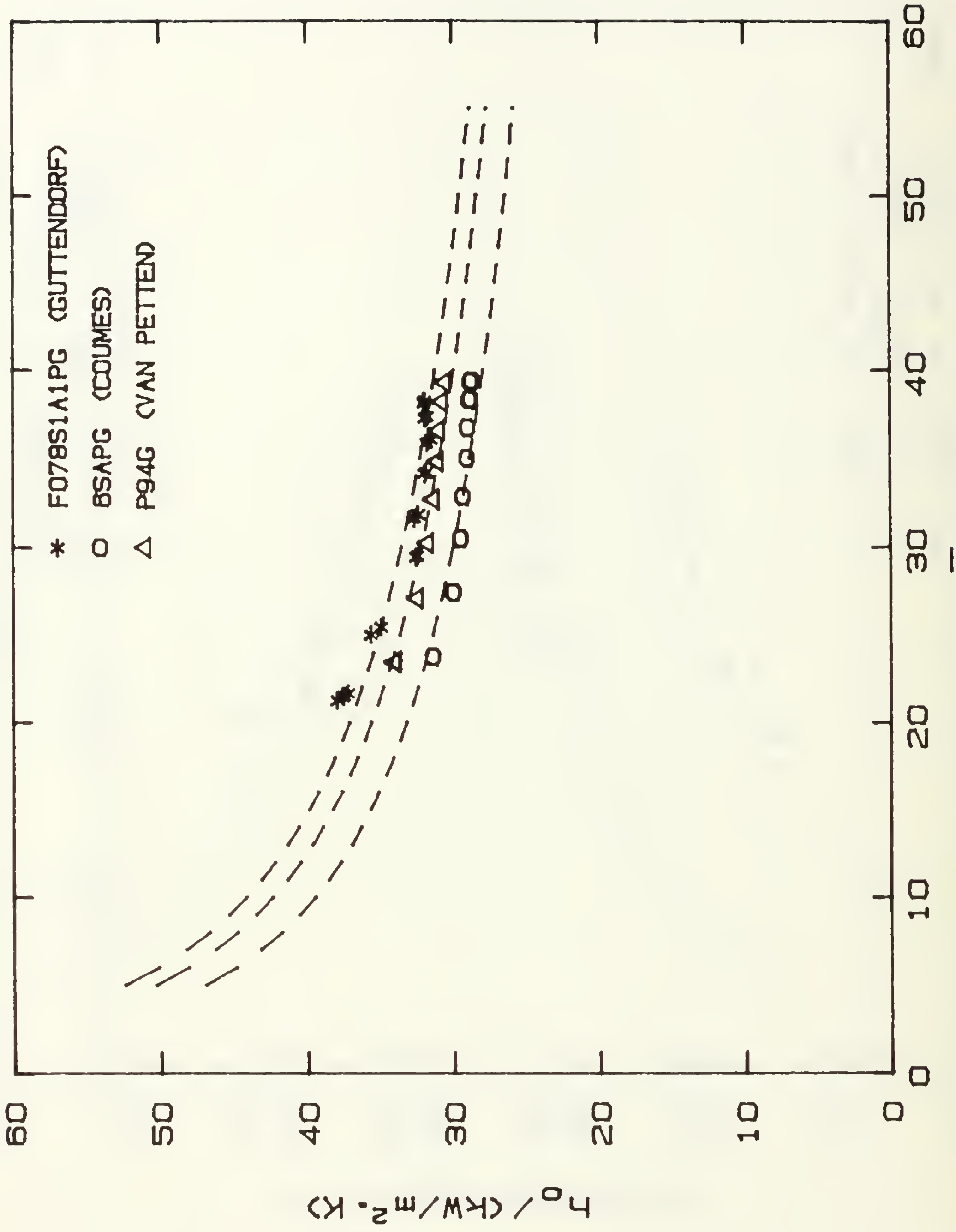

Figure 44. Repeatability of Tube F078 (Atmospheric)

croscopic investigation may give a reason for the differences). Again, all the enhancement ratios were based on the smooth tube values of α found from the current investigation. The enhancement ratios for all tubes at vacuum and atmospheric conditions based on an average Ci are listed in Tables 6 and 7. Based on the new small finned tube family results for fin spacings of 1.25, 1.5 and 1.75 mm, new enhancement ratio curves for the small tube family were obtained for vacuum and atmospheric conditions. Figures 47 and 48 show these new enhancement ratio curves along with the previously obtained enhancement ratio curves for the medium and large diameter tubes.

Table 6. SUMMARY OF ENHANCEMENTS AT VACUUM CONDITIONS (WITH INSERT)

Tube	Fin Spacing (mm)	Retention Angle (degrees)	Area Enhancement	Heat Transfer Enhancement
Small Tubes				
F074	0.25	180	2.85	1.74 1.72
F075	0.50	180	2.54	1.51 1.51
F076	1.00	156	2.15	1.71 1.66
F077	1.50	106	1.93	1.63
F078	2.00	88	1.77	1.75 1.74
F079	4.00	59	1.46	1.88
F090	0.25	180	1.85	1.88 1.87
F091	0.50	180	2.54	1.49 1.50
F092	1.00	156	2.15	1.82 1.82
F093	1.25	121	2.03	1.81 1.78
F094	1.50	106	1.93	2.16 2.14
F095	1.75	94	1.84	2.16 2.17
F086	1.00	139	2.28	1.88
Medium Tubes				
F006	1.50	84	1.88	2.57 2.59
F096	1.50	84	1.88	2.28 2.31
Large Tubes				
F083	1.50	72	1.86	3.05 3.22

Table 7. SUMMARY OF ENHANCEMENTS AT ATMOSPHERIC CONDITIONS (WITH INSERT)

Tube	Fin Spacing (mm)	Retention Angle (degrees)	Area Enhancement	Heat Transfer Enhancement
Small Tubes				
F074	0.25	180	2.85	2.40 2.50
F075	0.50	180	2.54	2.53 2.60
F076	1.00	134	2.15	3.15 3.17
F077	1.50	97	1.93	2.39 2.48
F078	2.00	81	1.77	2.26 2.33 2.34
F079	4.00	55	1.46	2.20
F090	0.25	180	1.85	2.94
F091	0.50	180	2.54	2.39
F092	1.00	134	2.15	2.43
F093	1.25	108	2.03	2.62
F094	1.50	97	1.93	2.67
F095	1.75	86	1.84	2.76
F086	1.00	121	2.28	2.90 2.99
Medium Tubes				
F006	1.50	78	1.88	3.20 3.32
F096	1.50	78	1.88	2.81 2.79
Large Tubes				
F083	1.50	67	1.86	3.42 3.48

E. EFFECTS OF SPIRAL INSERT

Another objective of this investigation was to determine reasons for the differences between data taken at QMC in London and data taken at NPS for a similar tube under similar operating conditions. The only difference in testing procedure was that the tests

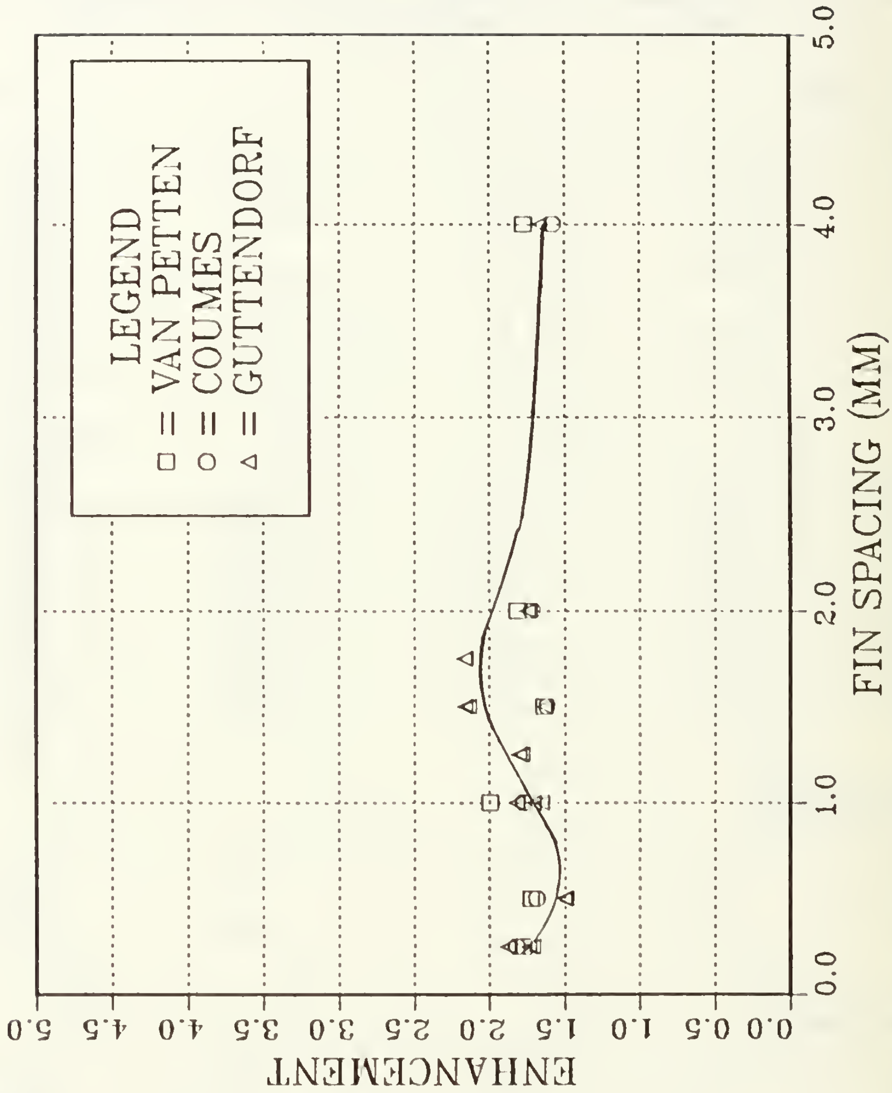

Figure 45. Enhancements for Small Tubes at Vacuum Conditions

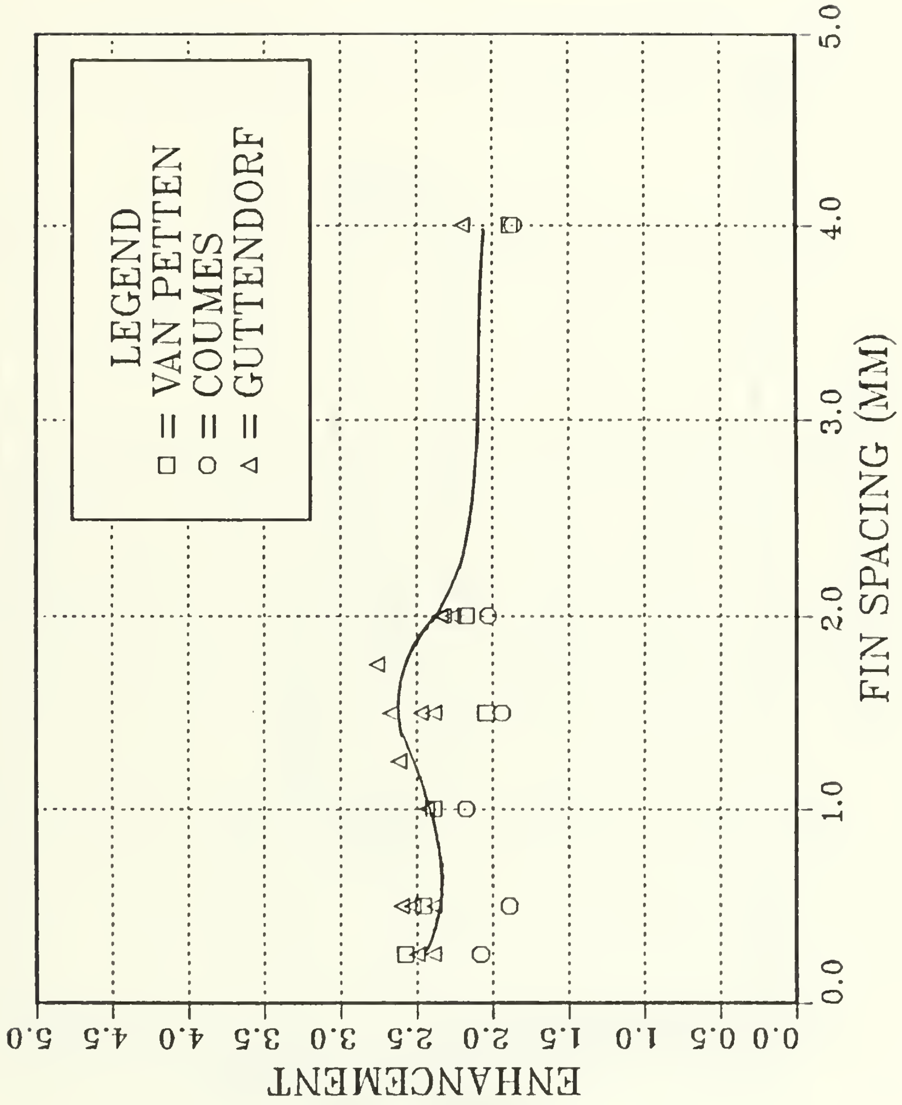

Figure 46. Enhancements for Small Tubes at Atmospheric Conditions

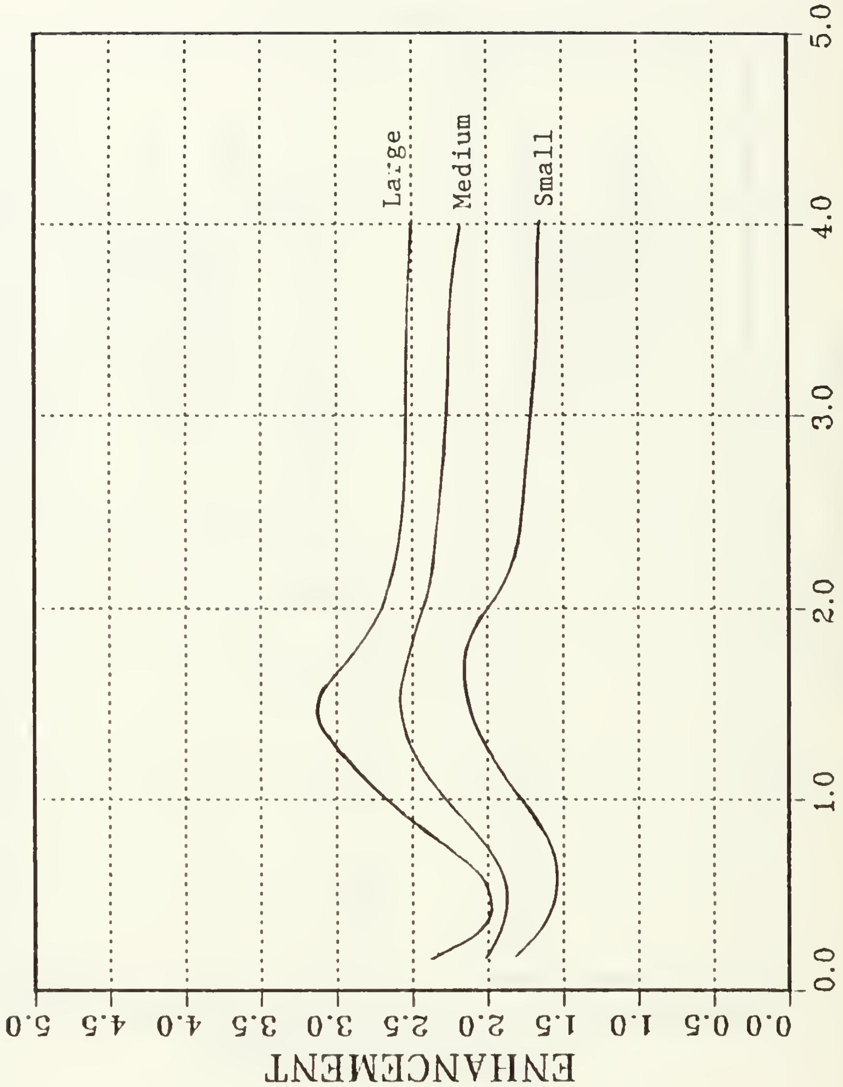

Figure 47. Enhancements for Small, Medium and Large Tubes (Vacuum)

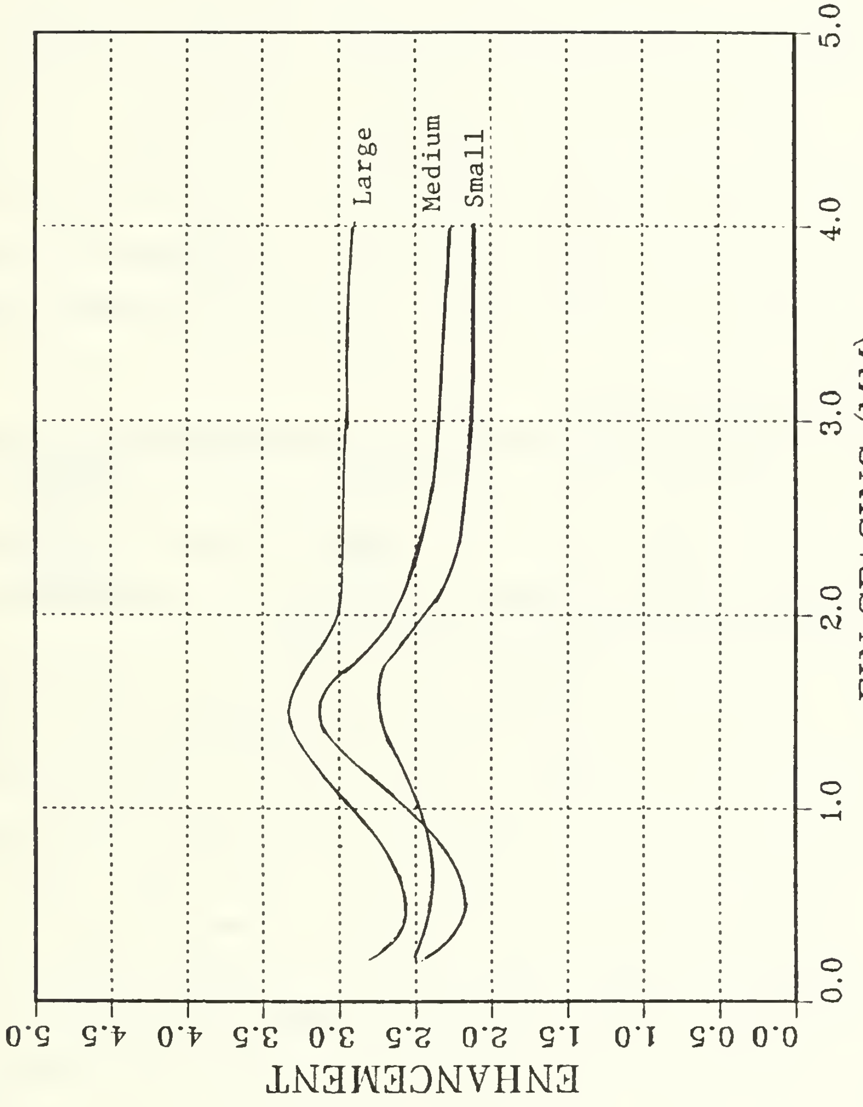

Figure 48. Enhancements for Small, Medium and Large Tubes (Atmospheric)

in London were done without an insert and the tests at NPS were done with an insert. It was decided that repeating the tests at NPS without the use of an insert would determine if the insert was the reason for the difference.

The use of an insert should not affect the outside heat-transfer coefficient. The insert was used at NPS because it was felt that it provided certain advantages in taking more accurate data. The insert increases the heat-transfer rate across the tube by promoting turbulence and better coolant mixing on the inside. This better mixing leads to an increase in the coolant temperature rise between the tube inlet and outlet. Although the outside of the tube may 'feel' an increase in the heat-transfer rate, it does not know the reason for it. It could equally be due to a higher coolant velocity. Since the coolant temperature rise is the key measurement made, a larger absolute value leads to less relative error in the calculated value of heat flux. One of the disadvantages of using an insert in reality would be the increased pressure drop, but in the present investigation, this was not of prime concern.

Figures 49 thru 54 show the results for the smooth tube tests done with and without and insert. Again the graphs plot the outside heat-transfer against the average temperature drop across the condensate film. As seen in the graphs, all of the data falls on the same line indicating what was expected, that there is no dependence on the use of an insert. The only effect is to increase the range of ΔT.

Figure 55 shows the enhancement ratios for the QMC and QMCNPS tubes at atmospheric conditions (QMC data are taken from Masuda [Ref. 31]). It can be seen that the results for the QMCNPS tube done with an insert are significantly higher than the corresponding QMC results. One may expect the opposite since the QMC tube has slightly longer fins and hence a larger outside surface area. However, when the QMCNPS tube was retested without the insert, the results agreed very well with the QMC results (QMC obtained a value of .907 for their smooth tube α as compared to a value of 1.04 found at NPS). The difference between the insert and no insert data for the QMCNPS tube led to retesting of all the finned tubes without an insert. In all cases, the results obtained when using no insert were significantly lower than those obtained when an insert was used. Furthermore, the difference was always greater at atmospheric conditions than at vacuum conditions. Figure 56 shows the results at atmospheric conditions for the new small family of finned tubes tested both with and without the insert as well as the QMC and QMCNPS (both with and without the insert) results (QMC only tested their tubes at atmospheric conditions). It is encouraging to see that QMC also found an optimal fin spacing of 1.5 mm for the small diameter tube. The QMC and

QMCNPS tubes had the same root diameter as the small family of tubes, however, they had taller thinner fins (see Table 1) resulting in a larger outer surface area. This should result in a higher heat transfer enhancement for both the QMC and QMCNPS tubes over that found for the small finned tubes at the same fin spacings. It can be seen in Figure 56 that the small tube enhancements obtained with an insert are higher than the QMC/QMCNPS enhancements (ie. opposite of what was expected). However, the small tube enhancements obtained without an insert fall below the QMC/QMCNPS enhancements as expected. The smooth tube values of α obtained without an insert are listed in Table 8. Tables 9 through 12 list the Sieder-Tate leading coefficients and the enhancement ratios for all finned tubes tested without an insert. Although absolute values between insert and no insert results differ, the trends in the tables are the same.

Table 8. SUMMARY OF SMOOTH TUBE ALPHAS (NO INSERT)

Diameter	Vacuum	Atmospheric
Small	1.01	1.04
Medium	0.94	0.89
Large	0.92	0.86

Table 9. SIEDER-TATE COEFFICIENTS (NO INSERT)

Tube	File Name	Vacuum	File Name	Atmospheric
Small Tubes				
S088	S088S0V3	.027	S088S0A2	.027
F074	F074S0V1	.029	F074S0A1	.030
			F074S0A2	.031
F075	F075S0V1	.028	F075S0A1	.027
F076	F076S0V1	.029	F076S0A1	.029
F077	F077S0V1	.028	F077S0A1	.030
F078	F078S0V1	.030	F078S0A1	.032
			F078S0A2	.030
F079	F079S0V1	.028	F079S0A1	.029
F090	F090S0V1	.027	F090S0A1	.029
F091	F091S0V1	.029	F091S0A1	.027
F092	F092S0V1	.027	F092S0A1	.032
F093	F093S0V1	.029	F093S0A1	.031
F094	F094S0V1	.028	F094S0A1	.031
F095	F095S0V1	.028	F095S0A1	.033
F086 (QMCNPS)	F086S0V1	.029	F086S0A1	.031
Medium Tubes				
S001	S001S0V2	.020	S001S0A2	.032
	S001S0V3	.030		
F006	F006S0V1	.034	F006S0A1	.043
F096	F096S0V1	.034	F096S0A1	.043
Large Tubes				
S089	S089S0V2	.031	S089S0A3	.037
	S089S0V3	.030		
	S089S0V4	.030		
F083	F083S0V1	.036	F083S0A1	.041
	F083S0V2	.036		

Table 10. AVERAGE SIEDER-TATE COEFFICIENTS (NO INSERT)

Diameter	Vacuum	Atmospheric
Small	.028	.030
Medium	.034	.043
Large	.036	.041

Table 11. SUMMARY OF ENHANCEMENTS AT VACUUM CONDITIONS (WITHOUT INSERT)

Tube	Fin Spacing (mm)	Retention Angle (degrees)	Area Enhancement	Heat Transfer Enhancement
Small Tubes				
F074	0.25	180	2.85	1.70
F075	0.50	180	2.54	1.54
F076	1.00	156	2.15	1.68
F077	1.50	106	1.93	1.59
F078	2.00	88	1.77	1.70
F079	4.00	59	1.46	1.67
F090	0.25	180	1.85	1.87
F091	0.50	180	2.54	1.49
F092	1.00	156	2.15	1.69
F093	1.25	121	2.03	1.70
F094	1.50	106	1.93	2.01
F095	1.75	94	1.84	2.04
F086	1.00	139	2.28	1.92
Medium Tubes				
F006	1.50	84	1.88	2.22
F096	1.50	84	1.88	2.00
Large Tubes				
F083	1.50	72	1.86	2.65 2.60

Table 12. SUMMARY OF ENHANCEMENTS AT ATMOSPHERIC CONDITIONS (WITHOUT INSERT)

Tube	Fin Spacing (mm)	Retention Angle (degrees)	Area Enhancement	Heat Transfer Enhancement
Small Tubes				
F074	0.25	180	2.85	2.02
				2.12
F075	0.50	180	2.54	2.09
F076	1.00	134	2.15	2.58
F077	1.50	97	1.93	2.14
F078	2.00	81	1.77	2.02
				1.90
F079	4.00	55	1.46	1.97
F090	0.25	180	1.85	2.09
F091	0.50	180	2.54	1.65
F092	1.00	134	2.15	1.94
F093	1.25	108	2.03	2.20
F094	1.50	97	1.93	2.32
F095	1.75	86	1.84	2.39
F086	1.00	121	2.28	2.40
Medium Tubes				
F006	1.50	78	1.88	2.03
F096	1.50	78	1.88	1.67
Large Tubes				
F083	1.50	67	1.86	1.99

This difference between the finned tube results obtained with and without the use of an insert has caused concern over the processing technique currently used. The current processing technique uses the Sieder-Tate correlation for the inside heat-transfer coefficient (Equation (4.11)) varying the leading coefficient (Ci) to compensate for the use of the insert. However, this correlation, in its present form, is not strictly valid when an insert is used. But this leads to the question: Why are only the finned tube results affected and not the smooth tube results? The difference may be due to differences in the outer tube flooding conditions between the smooth and finned tubes. If it turns out that the inside heat-transfer coefficient is dependent on the outside flooding conditions, then there would be a different correlation for each different finned tube. This has re-

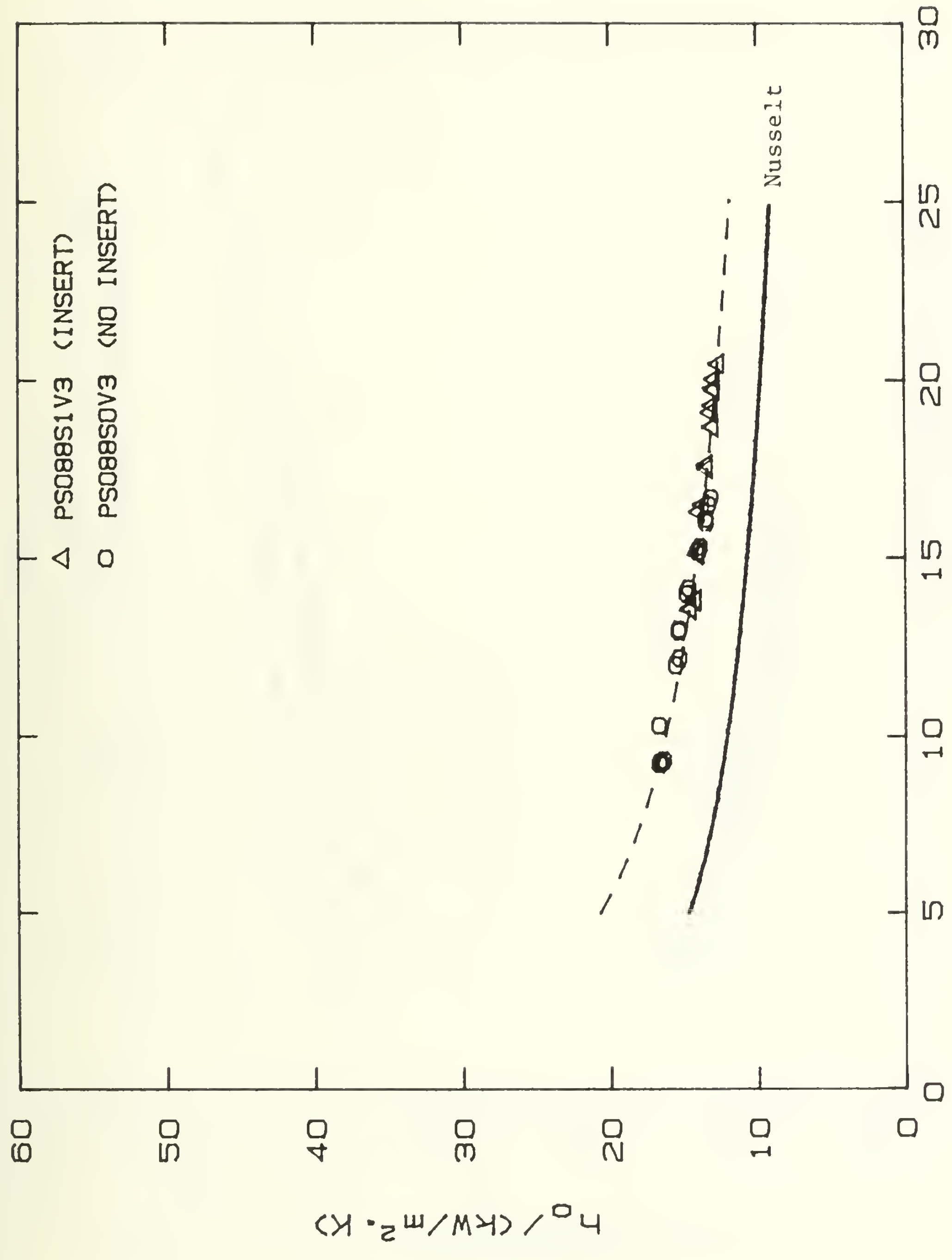

Figure 49. Insert and No Insert Results for Small Smooth Tube (Vacuum)

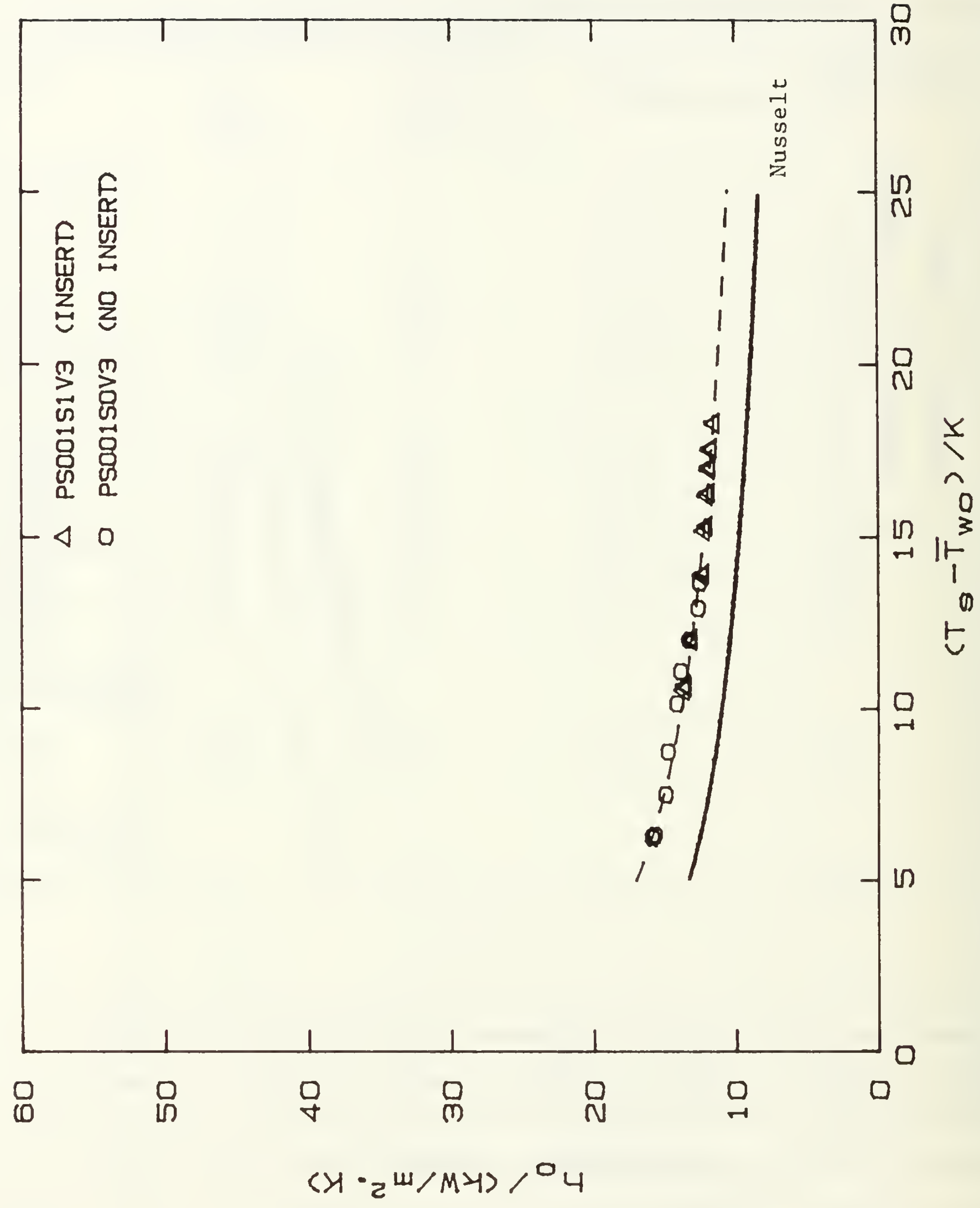

Figure 50. Insert and No Insert Results for Medium Smooth Tube (Vacuum)

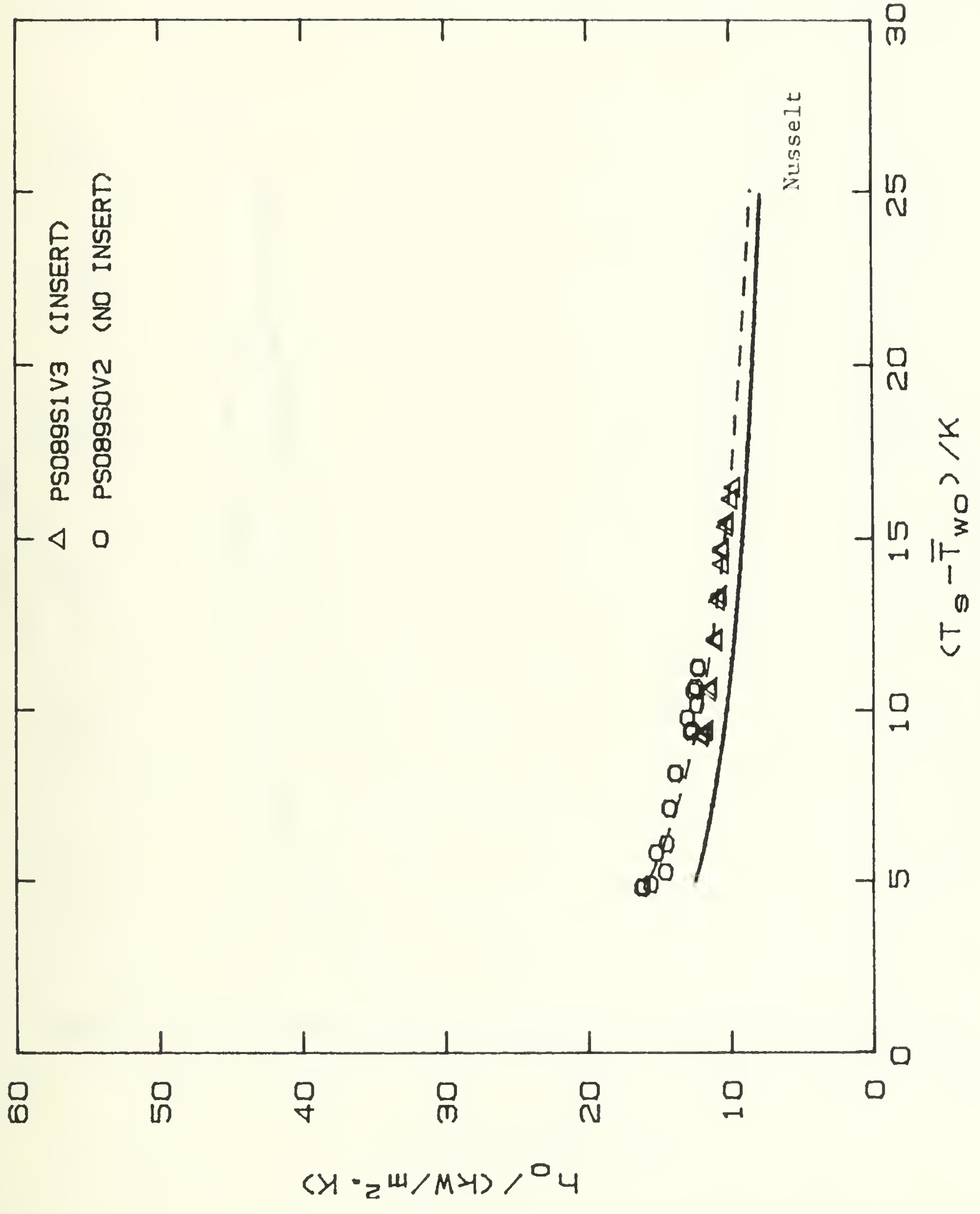

Figure 51. Insert and No Insert Results for Large Smooth Tube (Vacuum)

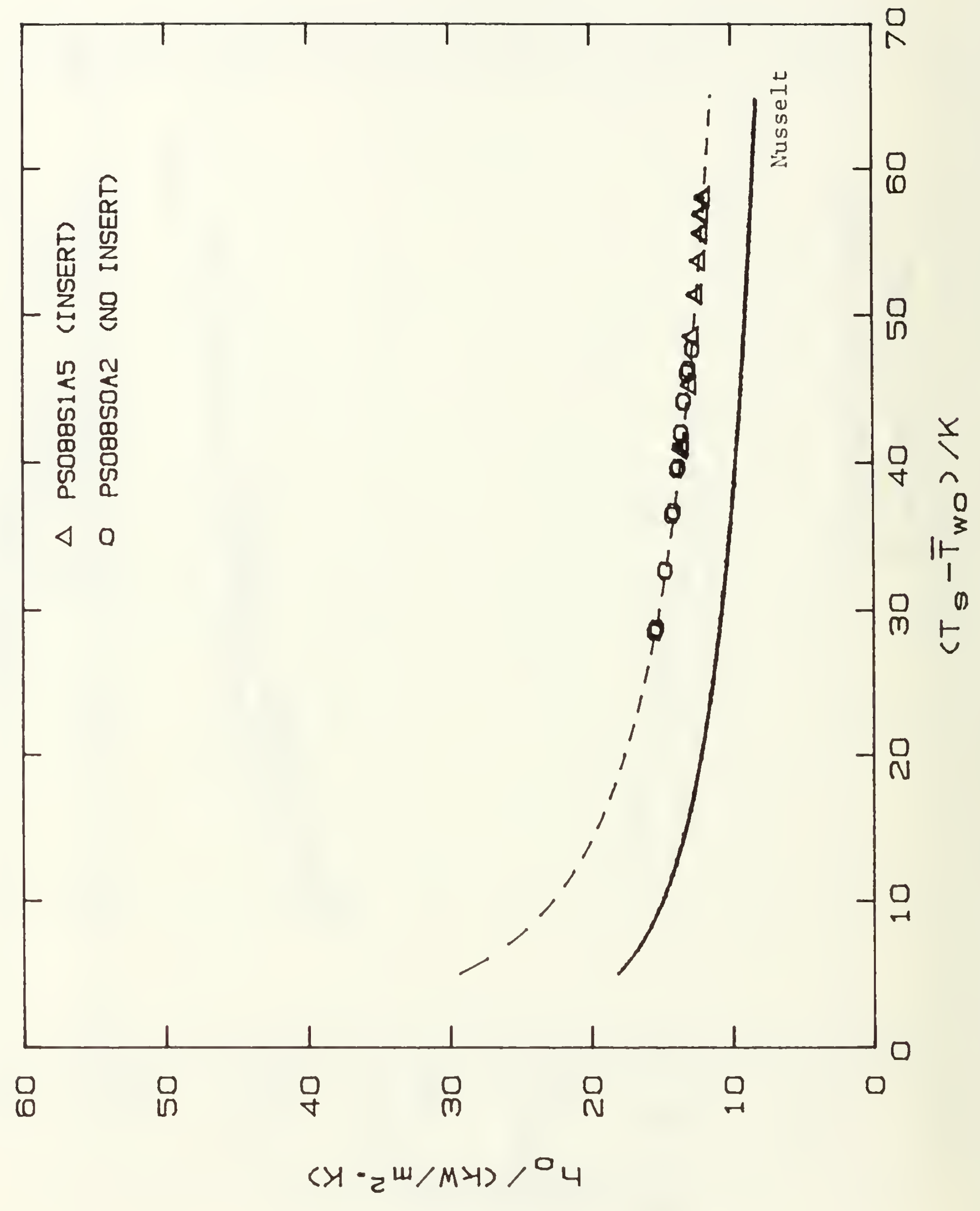

Figure 52. Insert and No Insert Results for Small Smooth Tube (Atmospheric)

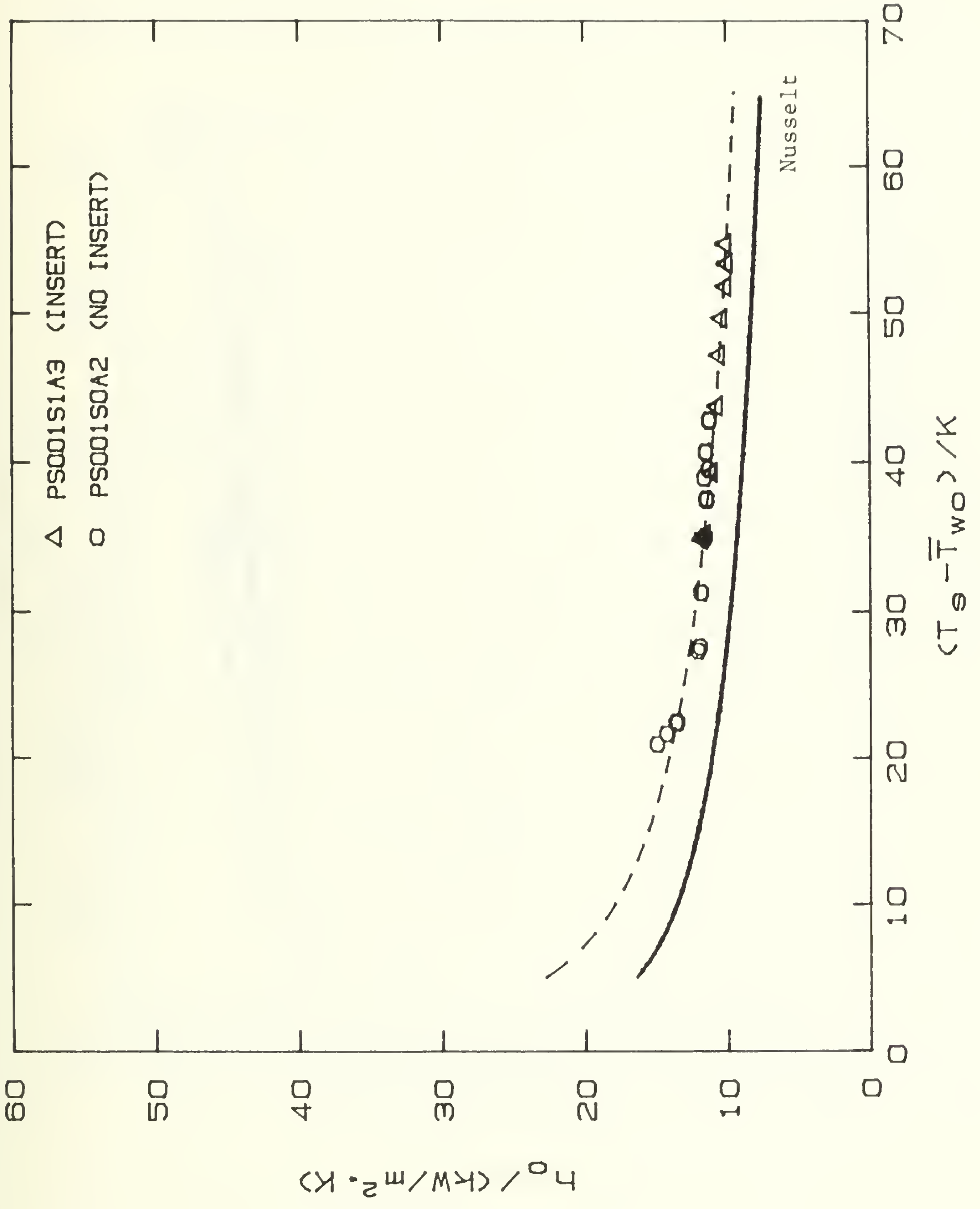

Figure 53. Insert and No Insert Results for Medium Smooth Tube (Atmospheric)

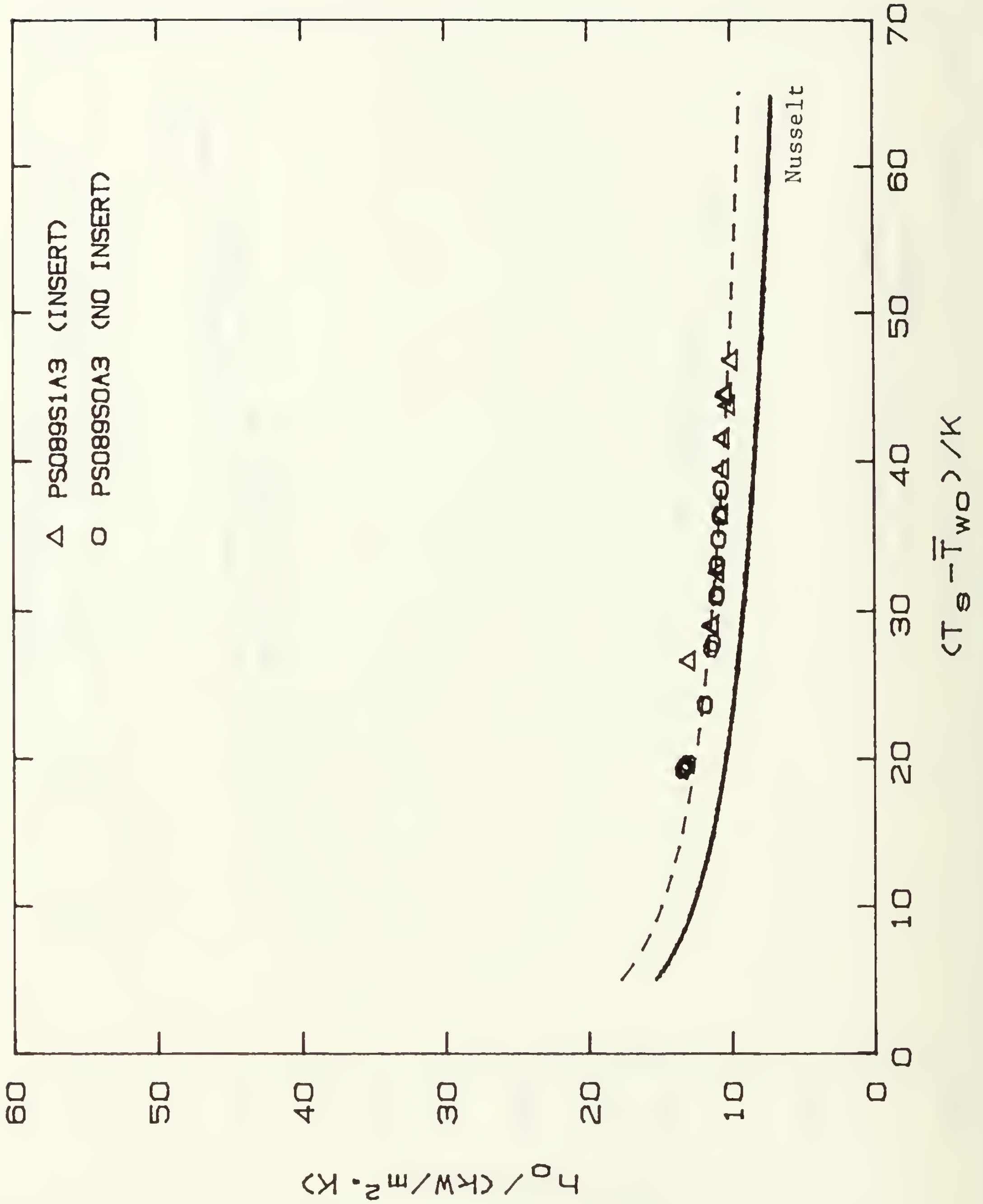

Figure 54. Insert and No Insert Results for Large Smooth Tube (Atmospheric)

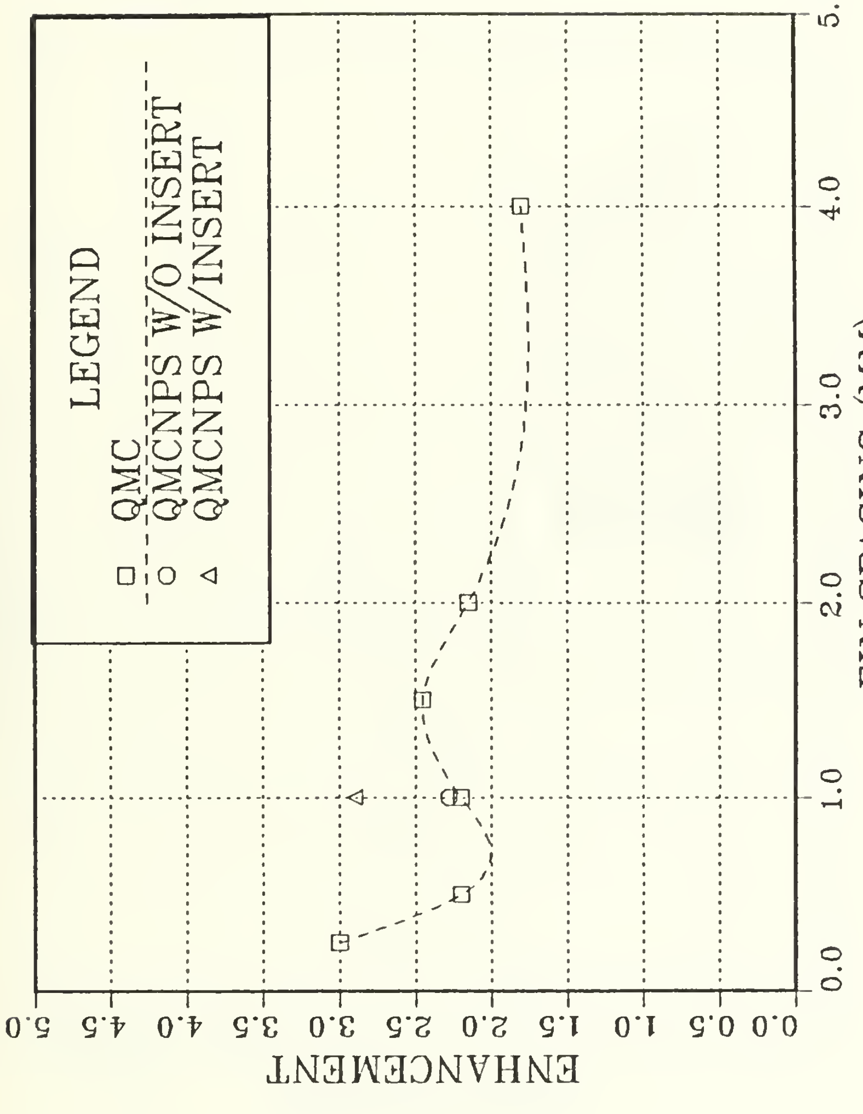

Figure 55. Enhancements for QMC and QMCNPS Showing Influence of Insert at Atmospheric Conditions

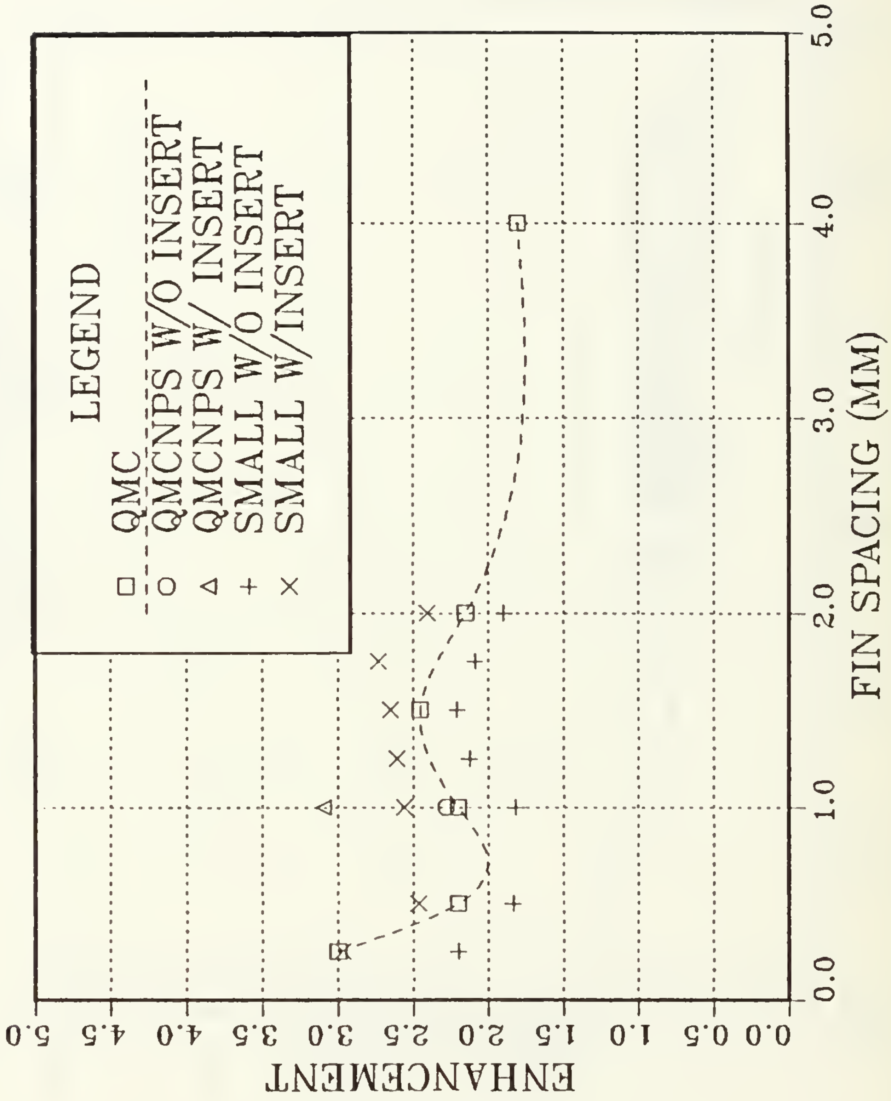

Figure 56. Enhancement Ratios for New Small Family with and without Insert at Atmospheric Conditions

sulted in the need to develop a more accurate and applicable correlation for the inside heat-transfer coefficient. The inside tube conditions may need to be investigated to the same degree as the outside tube conditions. An alternative is the use of instrumented tubes, thus doing away with the need for the inside correlation by being to able to measure the outer wall temperature directly.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Good repeatability with previous data for large and medium finned tubes at both vacuum and atmospheric conditions was obtained.
2. Discrepancies between the old small finned tube family and the new small finned tube family at fin spacings between 1.0 and 2.0 mm suggest that the old small finned tube with a fin spacing of 1.5 mm gave inaccurate results. Present results suggest a peak instead of a dip in the enhancement curve at this fin spacing.
3. These suggest an an optimum fin spacing for filmwise condensation of steam on integral finned tubes of 1.5 mm which seems to be independent of tube root diameter and vapor pressure.
4. The values of α for the smooth tube for cases with and without an insert differed by approximately 4-5%. However, this difference caused no effect when comparing insert/no insert smooth tube results.
5. For finned tubes, the use of an insert had a significant effect. Enhancement ratios were consistently lower when no insert was used leading to better agreement between the QMC data and the QMCNPS data.
6. The use of the Sieder-Tate correlation in its present form may not be accurate in representing the inside heat-transfer coefficient for finned tubes when an insert is used. There is a need to develop a better inside correlation.

B. RECOMMENDATIONS

1. Develop a more accurate correlation for the inside heat-transfer coefficient. One possibility is to introduce an extra constant into the Sieder-Tate correlation such as:

$$h_i = C_i \frac{k_c}{D_i} Re^{0.8} Pr^{0.333} \left(\frac{\mu_c}{\mu_w} \right)^{0.14} + C_2$$

2. Manufacture instrumented finned tubes to eliminate the need for a correlation for the inside heat-transfer coefficient.
3. Conduct condensation tests on finned tubes of different materials (ie. titanium, which is of interest to the U.S. Navy because of its light weight and high resistance to corrosion).
4. Conduct condensation tests using different fluids to study, in more detail, the effects of surface tension.
5. Replace the mercury-in-glass manometer with a direct reading pressure gage as this was found to be one of the main sources of error.

APPENDIX A. QUARTZ THERMOMETER CALIBRATION DATA

The HP 2804A Quartz Crystal Thermometer (Serial number: 2244A01192) was calibrated on March 28, 1990. The calibration was performed at low resolution on two temperature measuring probes, T1 (Serial number: 2120A-00707 with dial setting 481) and T2 (Serial number: 2120A-60459 with dial setting 510).

Table 13. CALIBRATION DATA

Test Pt. (deg C)	Calibration 'Omega'	Calibration Temperature (deg C)	T1 (deg C)	Error (deg C)	T2 (deg C)	Error (deg C)
Ice Pt.		00.00	00.00	00.00	00.01	+0.01
15	27.625	20.26	20.24	-0.02	20.25	-0.01
40	29.420	38.03	37.99	-0.04	38.04	+0.01

- The Ice Point uncertainty was +/- 0.01 deg C
- The Bath uncertainty was +/- 0.02 deg C
- The test point temperature was measured using a platinum resistance thermometer.

APPENDIX B. SYSTEM STARTUP AND SHUTDOWN PROCEDURES

When preparing the system at the beginning of a data run, the system is started in the following manner:

1. Ensure distilled water level in the boiler is 4 to 6 inches above the heating elements. To fill the boiler, attach hose from the distilled water container to the bottom of the boiler and gravity feed the boiler. Ensure the vent valve on the side of the auxiliary condenser is open when filling or draining the boiler.
2. Check the oil level in the purge pump and check to insure system vent valve is shut.
3. Turn on the data acquisition system, computer and printer. Load software program DRP12B or current program.
4. Open the fill valve for the tube coolant water sump (valve is located to the left of the boiler control panel).
5. Turn on the cooling water supply pumps and adjust the tube flow rate from 20% to 60% and check for leaks. Reset flow rate to 20%.
6. Open valves from tap water system to auxiliary condenser and adjust coolant flow rate through auxiliary condenser to at least 30% and check for leaks.
7. Energize heaters and adjust voltage to approximately 50 volts for warmup. To energize heaters there are three switches which must be turned on. The first is located in power panel p5 located in the main hallway outside the lab and is labeled switch 3 or heater controller room 106. The second is the heater load bank circuit breaker located on the side of the boiler control panel. The third is the condensing rig boiler power switch on the front of the boiler control panel.
8. If conducting a vacuum run, energize the vacuum purge pump then open the system vent valve (a single turn).
9. Start running software program DRP12B by pressing "run" key on the keyboard. The program is very user friendly. To take data for a tube the questions should be answered as follows:
   - Select fluid... Enter fluid in use
   - Select option...Enter 0 to take data
   - Enter Month, date and time...press "enter"
   - Enter input mode...enter 0 for 3054A (this is for new data)
   - Select Ci...enter 0 to find a Ci, enter 2 to use Ci value stored in the program.
   - Give name for raw data file...enter name
   - Enter geometry code...enter finned or plain
   - Enter 0 if no insert...just press "enter" if there is an insert
   - Select tube type...enter 0 for thick walled tubes
   - Select tube material...enter 0 for copper
   - Select tube diameter
   - Enter pressure condition...enter 0 for vacuum, 1 for atmospheric
   - Would you like to create a file for NR vs F (this is for vapor velocity tests)...enter 0 for no

- Give name for plot file...easiest to just use raw data file name preceded by a p
- Select output...For new data it is best to enter 1 for long
- Would you like to check ng concentration...you must answer yes to this for the first data point.
- Enter flowmeter reading...enter 2 digit number (ie. 20 or 54 etc.)
- Enter manometer readings...enter in mmHg (ie. 415) left column is a positive value, right column is a negative value.
- Continue for all data points at various flowmeter readings.

10. Only answer the program questions up to "Enter flowmeter readings". Monitor system temperature using the thermocouple voltage reading until the system has been warmed up.

11. Monitor system temperature and system pressure carefully to prevent a system overpressure during warmup (especially at atmospheric conditions).

12. If conducting a vacuum run, wait until the system pressure reaches approximately 120 mmHg (lefthand column) then gradually increase voltage in 10 volt increments to 90 volts. Obtain desired operating condition by manually controlling flow through the auxiliary condenser.

13. If conducting atmospheric run, open system vent valve and purge system drain valve. Allow the system to warm up for least 30 minutes at 50 volts then begin increasing voltage in 10 volt increments until approximately 100 volts is reached. Watch for system pressure to drop (this occurs when vapor travels down over auxiliary condenser and begins condensing), then close system vent valve and purge system drain valve. Energize vacuum pump and open system vent valve 1/4 of a turn. Continue to increase voltage in 10-20 volt increments to 175 volts while throttling flow through the auxiliary condenser to obtain desired operating conditions.

14. Allow vacuum pump to operate continuously.

15. Monitor condensation process using the glass viewing window. Use a heated air blower (hair dryer) to keep the window free of fog and moisture.

16. If tube is not wetted, manually turn the tube until it is wetted by turning the fitting on the cooling water inlet to the tube.

17. When taking readings, be sure to check flowmeter setting before entering it into the computer (it has a tendency to fluctuate slightly).

18. If conducting vacuum and atmospheric runs on the same day, always conduct the vacuum run first. If atmospheric run is done first, it takes too long for the system to cool to vacuum run operating temperatures.

The system is secured in the following manner:

1. Secure power to the boiler heating elements.

2. Isolate and secure the purge system.

3. Open vent valve on the side of the auxiliary condenser to allow the system to come to atmospheric pressure. Do not use the valve to the purge system to raise system pressure because there is a possibility of oil and contaminants from the purge system lines getting into the system.

4. After the system is at atmospheric pressure, open purge system drain valve.
5. Continue circulating cooling water through the auxiliary condenser and test tube at reduced flow rates to assist in cooling down the system.
6. Turn off computer, data acquisition system, and printer.
7. It is necessary to periodically change the distilled water in the boiler. However it is important that the boiler is never drained unless completely cool.

APPENDIX C. UNCERTAINTY ANALYSIS

There will always be uncertainties associated with any experimentally determined results. These uncertainties are the result of many factors including the accuracy of the measuring device, the calibration of the device and the operator's experience. Although the uncertainty for a single measurement may be small, an equation or data reduction scheme which combines numerous measurements with small uncertainties may generate results with much greater uncertainties. In cases where the final results show large uncertainties, it may be necessary to disregard the experimental results which generated the large uncertainty. The uncertainties of the measured quantities in this investigation were determined using the following expression suggested by Kline and McClintok [Ref. 32]:

$$W_R = \left[\left(\frac{\partial R}{\partial x_1} W_1 \right)^2 + \left(\frac{\partial R}{\partial x_2} W_2 \right)^2 + \cdots \cdots + \left(\frac{\partial R}{\partial x_n} W_n \right)^2 \right]^{\frac{1}{2}}$$

where

W_R = *the uncertainty of the desired dependent variable*

$x_1, x_2, \ldots, x_n$ = *the measured independent variables*

$W_1, W_2, \ldots, W_n$ = *the uncertainties in the measured variables*

A complete discussion on the uncertainty analysis used for this experiment is given by Georgiadis [Ref. 27]. A program, designed by Mitrou [Ref. 33] was used to calculate the uncertainties for this experiment. Sample outputs of the uncertainty evaluations follow.

```
DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:               S088S1A5
Pressure Condition:      Atmospheric (101 kPa)
Vapor Temperature                = 100.02      (Deg C)
Water Flow Rate (%)              =  20.00
Water Velocity                   =   2.07       (m/s)
Heat Flux                        =   3.690E+05  (W/m^2)
Tube-metal thermal conduc.       = 385.0        (W/m.K)
Sieder-Tate constant             =   0.0510


UNCERTAINTY ANALYSIS:

    VARIABLE                   PERCENT UNCERTAINTY

Mass Flow Rate, Md                    2.99
Reynolds Number, Re                   3.11
Heat Flux, q                          3.02
Log-Mean-Tem Diff, LMTD                .15
Wall Resistance, Rw                   2.63
Overall H.T.C., Uo                    3.03
Water-Side H.T.C., Hi                 6.40
Vapor-Side H.T.C., Ho                 9.15
```

```
DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:               S088S1A5
Pressure Condition:      Atmospheric (101 kPa)
Vapor Temperature                = 100.09      (Deg C)
Water Flow Rate (%)              =  66.00
Water Velocity                   =   6.51       (m/s)
Heat Flux                        =   4.479E+05  (W/m^2)
Tube-metal thermal conduc.       = 385.0        (W/m.K)
Sieder-Tate constant             =   0.0510


UNCERTAINTY ANALYSIS:

    VARIABLE                   PERCENT UNCERTAINTY

Mass Flow Rate, Md                    0.95
Reynolds Number, Re                   1.27
Heat Flux, q                          1.12
Log-Mean-Tem Diff, LMTD                .38
Wall Resistance, Rw                   2.63
Overall H.T.C., Uo                    1.18
Water-Side H.T.C., Hi                 5.98
Vapor-Side H.T.C., Ho                 2.87
```

```
DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:               S001S1A3
Pressure Condition:      Atmospheric (101 kPa)
Vapor Temperature                =  99.92        (Deg C)
Water Flow Rate (%)              =  20.00
Water Velocity                   =   1.17         (m/s)
Heat Flux                        =   4.104E+05   (W/m^2)
Tube-metal thermal conduc.       = 385.0         (W/m.K)
Sieder-Tate constant             =   0.0681


UNCERTAINTY ANALYSIS:

    VARIABLE                 PERCENT UNCERTAINTY

Mass Flow Rate, Md                  2.99
Reynolds Number, Re                 3.09
Heat Flux, q                        3.02
Log-Mean-Tem Diff, LMTD              .14
Wall Resistance, Rw                 2.67
Overall H.T.C., Uo                  3.02
Water-Side H.T.C., Hi               3.86
Vapor-Side H.T.C., Ho               7.56

DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:               S001S1A3
Pressure Condition:      Atmospheric (101 kPa)
Vapor Temperature                = 100.06        (Deg C)
Water Flow Rate (%)              =  80.00
Water Velocity                   =   4.42         (m/s)
Heat Flux                        =   5.435E+05   (W/m^2)
Tube-metal thermal conduc.       = 385.0         (W/m.K)
Sieder-Tate constant             =   0.0681


UNCERTAINTY ANALYSIS:

    VARIABLE                 PERCENT UNCERTAINTY

Mass Flow Rate, Md                  0.79
Reynolds Number, Re                 1.09
Heat Flux, q                         .98
Log-Mean-Tem Diff, LMTD              .38
Wall Resistance, Rw                 2.67
Overall H.T.C., Uo                  1.05
Water-Side H.T.C., Hi               3.08
Vapor-Side H.T.C., Ho               1.88
```

```
DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:                S089S1A3
Pressure Condition:       Atmospheric (101 kPa)
Vapor Temperature                 = 100.00       (Deg C)
Water Flow Rate (%)               =  20.00
Water Velocity                    =    1.16       (m/s)
Heat Flux                         =    4.325E+05  (W/m^2)
Tube-metal thermal conduc.        = 385.0        (W/m.K)
Sieder-Tate constant              =    0.0647


UNCERTAINTY ANALYSIS:

    VARIABLE                  PERCENT UNCERTAINTY

Mass Flow Rate, Md                 3.00
Reynolds Number, Re                3.10
Heat Flux, q                       3.03
Log-Mean-Tem Diff, LMTD             .13
Wall Resistance, Rw                2.67
Overall H.T.C., Uo                 3.03
Water-Side H.T.C., Hi              3.98
Vapor-Side H.T.C., Ho              8.91

DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:                S089S1A3
Pressure Condition:       Atmospheric (101 kPa)
Vapor Temperature                 =  99.94       (Deg C)
Water Flow Rate (%)               =  80.00
Water Velocity                    =    4.41       (m/s)
Heat Flux                         =    6.193E+05  (W/m^2)
Tube-metal thermal conduc.        = 385.0        (W/m.K)
Sieder-Tate constant              =    0.0647


UNCERTAINTY ANALYSIS:

    VARIABLE                  PERCENT UNCERTAINTY

Mass Flow Rate, Md                 0.79
Reynolds Number, Re                1.10
Heat Flux, q                        .96
Log-Mean-Tem Diff, LMTD             .33
Wall Resistance, Rw                2.67
Overall H.T.C., Uo                 1.02
Water-Side H.T.C., Hi              3.24
Vapor-Side H.T.C., Ho              2.20
```

```
DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:             F006S1V1
Pressure Condition:    Vacuum (11 kPa)
Vapor Temperature              =  48.50       (Deg C)
Water Flow Rate (%)            =  20.00
Water Velocity                 =   1.16        (m/s)
Heat Flux                      =   1.978E+05  (W/m^2)
Tube-metal thermal conduc.     = 385.0        (W/m.K)
Sieder-Tate constant           =   0.0666


UNCERTAINTY ANALYSIS:

    VARIABLE                 PERCENT UNCERTAINTY

Mass Flow Rate, Md                 3.00
Reynolds Number, Re                3.10
Heat Flux, q                       3.04
Log-Mean-Tem Diff, LMTD             .29
Wall Resistance, Rw                2.67
Overall H.T.C., Uo                 3.06
Water-Side H.T.C., Hi              3.91
Vapor-Side H.T.C., Ho             23.93

DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:             F006S1V1
Pressure Condition:    Vacuum (11 kPa)
Vapor Temperature              =  48.48       (Deg C)
Water Flow Rate (%)            =  80.00
Water Velocity                 =   4.40        (m/s)
Heat Flux                      =   3.536E+05  (W/m^2)
Tube-metal thermal conduc.     = 385.0        (W/m.K)
Sieder-Tate constant           =   0.0666


UNCERTAINTY ANALYSIS:

    VARIABLE                 PERCENT UNCERTAINTY

Mass Flow Rate, Md                 0.79
Reynolds Number, Re                1.11
Heat Flux, q                       1.08
Log-Mean-Tem Diff, LMTD             .59
Wall Resistance, Rw                2.67
Overall H.T.C., Uo                 1.23
Water-Side H.T.C., Hi              3.15
Vapor-Side H.T.C., Ho              5.08
```

```
DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:              F077S1V2
Pressure Condition:     Vacuum (11 kPa)
Vapor Temperature                =  48.61        (Deg C)
Water Flow Rate (%)              =  20.00
Water Velocity                   =   2.06         (m/s)
Heat Flux                        =   1.590E+05  (W/m^2)
Tube-metal thermal conduc.       = 385.0         (W/m.K)
Sieder-Tate constant             =   0.0512


UNCERTAINTY ANALYSIS:

    VARIABLE                     PERCENT UNCERTAINTY

Mass Flow Rate, Md                    3.00
Reynolds Number, Re                   3.13
Heat Flux, q                          3.05
Log-Mean-Tem Diff, LMTD                .35
Wall Resistance, Rw                   2.63
Overall H.T.C., Uo                    3.07
Water-Side H.T.C., Hi                 6.38
Vapor-Side H.T.C., Ho                18.22

DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:              F077S1V2
Pressure Condition:     Vacuum (11 kPa)
Vapor Temperature                =  48.72        (Deg C)
Water Flow Rate (%)              =  66.00
Water Velocity                   =   6.48         (m/s)
Heat Flux                        =   2.262E+05  (W/m^2)
Tube-metal thermal conduc.       = 385.0         (W/m.K)
Sieder-Tate constant             =   0.0512


UNCERTAINTY ANALYSIS:

    VARIABLE                     PERCENT UNCERTAINTY

Mass Flow Rate, Md                    0.96
Reynolds Number, Re                   1.29
Heat Flux, q                          1.30
Log-Mean-Tem Diff, LMTD                .76
Wall Resistance, Rw                   2.63
Overall H.T.C., Uo                    1.50
Water-Side H.T.C., Hi                 5.96
Vapor-Side H.T.C., Ho                 5.49
```

```
DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:                 F094S1V1
Pressure Condition:        Vacuum (11 kPa)
Vapor Temperature                  =  48.40        (Deg C)
Water Flow Rate (%)                =  20.00
Water Velocity                     =   2.06         (m/s)
Heat Flux                          =   1.698E+05  (W/m^2)
Tube-metal thermal conduc.         = 385.0         (W/m.K)
Sieder-Tate constant               =   0.0512


UNCERTAINTY ANALYSIS:

    VARIABLE                  PERCENT UNCERTAINTY

Mass Flow Rate, Md                     3.01
Reynolds Number, Re                    3.14
Heat Flux, q                           3.05
Log-Mean-Tem Diff, LMTD                 .34
Wall Resistance, Rw                    2.63
Overall H.T.C., Uo                     3.07
Water-Side H.T.C., Hi                  6.39
Vapor-Side H.T.C., Ho                 27.79

DATA FOR THE UNCERTAINTY ANALYSIS:

File Name:                 F094S1V1
Pressure Condition:        Vacuum (11 kPa)
Vapor Temperature                  =  48.46        (Deg C)
Water Flow Rate (%)                =  66.00
Water Velocity                     =   6.47         (m/s)
Heat Flux                          =   2.627E+05  (W/m^2)
Tube-metal thermal conduc.         = 385.0         (W/m.K)
Sieder-Tate constant               =   0.0512


UNCERTAINTY ANALYSIS:

    VARIABLE                  PERCENT UNCERTAINTY

Mass Flow Rate, Md                     0.96
Reynolds Number, Re                    1.30
Heat Flux, q                           1.24
Log-Mean-Tem Diff, LMTD                 .66
Wall Resistance, Rw                    2.63
Overall H.T.C., Uo                     1.40
Water-Side H.T.C., Hi                  5.97
Vapor-Side H.T.C., Ho                  7.94
```

APPENDIX D. RAW DATA

The names for the raw data files for each tube are listed in Tables 4 and 9 in Chapter 5. The actual raw data files follow:

Tube Number: 88
File Name: S088S1V3
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	19.91	21.62	48.51	1.71
2	1.17	19.91	21.62	48.54	1.71
3	1.49	19.68	21.11	48.41	1.43
4	1.49	19.68	21.11	48.37	1.43
5	1.87	19.52	20.75	48.32	1.22
6	1.87	19.52	20.74	48.41	1.21
7	2.25	19.41	20.45	48.29	1.05
8	2.25	19.41	20.47	48.49	1.06
9	2.63	19.32	20.25	48.62	.93
10	2.63	19.32	20.25	48.67	.93
11	3.01	19.25	20.09	48.38	.84
12	3.01	19.25	20.09	48.57	.84
13	3.39	19.19	19.94	48.30	.76
14	3.39	19.18	19.94	48.41	.76
15	3.66	19.14	19.85	48.22	.71
16	3.66	19.14	19.85	48.64	.71
17	1.17	19.87	21.57	48.62	1.70
18	1.17	19.88	21.57	48.63	1.70

Tube Number: 88
File Name: S088S1A5
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	19.55	24.32	100.02	4.77
2	1.17	19.55	24.33	99.89	4.78
3	1.49	19.32	23.25	99.87	3.93
4	1.49	19.32	23.26	99.91	3.94
5	1.87	19.15	22.46	99.79	3.31
6	1.87	19.15	22.47	99.85	3.32
7	2.25	19.03	21.88	99.87	2.85
8	2.25	19.03	21.89	99.88	2.86
9	2.63	18.94	21.44	99.92	2.50
10	2.63	18.94	21.44	99.95	2.50
11	3.01	18.87	21.10	99.88	2.23
12	3.01	18.87	21.11	100.07	2.23
13	3.39	18.81	20.84	99.80	2.02
14	3.39	18.81	20.83	99.90	2.02
15	3.66	18.78	20.66	100.09	1.89
16	3.66	18.78	20.66	99.90	1.89
17	1.17	19.55	24.32	100.11	4.77
18	1.17	19.55	24.33	100.24	4.78

Tube Number: 01
File Name: S001S1V3
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	19.83	21.69	48.48	1.86
2	1.17	19.82	21.70	48.68	1.88
3	1.49	19.62	21.22	48.39	1.59
4	1.49	19.62	21.21	48.30	1.59
5	1.98	19.43	20.73	48.39	1.30
6	1.98	19.44	20.73	48.42	1.29
7	2.52	19.31	20.39	48.43	1.09
8	2.52	19.30	20.40	48.40	1.10
9	3.01	19.23	20.17	48.39	.94
10	3.01	19.23	20.19	48.41	.95
11	3.44	19.18	20.03	48.54	.85
12	3.44	19.19	20.04	48.44	.85
13	3.87	19.14	19.91	48.36	.76
14	3.87	19.14	19.91	48.42	.76
15	4.42	19.10	19.77	48.45	.67
16	4.42	19.10	19.77	48.43	.67
17	1.17	19.90	21.76	48.49	1.87

Tube Number: 01
File Name: S001S1A3
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	19.62	24.92	99.92	5.30
2	1.17	19.62	24.92	99.76	5.29
3	1.49	19.45	23.84	99.94	4.39
4	1.49	19.45	23.84	99.94	4.39
5	1.98	19.27	22.82	100.01	3.55
6	1.98	19.27	22.82	99.99	3.56
7	2.52	19.14	22.09	99.94	2.95
8	2.52	19.14	22.09	99.93	2.95
9	3.01	19.07	21.62	99.91	2.55
10	3.01	19.07	21.62	99.87	2.55
11	3.44	19.02	21.27	99.95	2.25
12	3.44	19.02	21.27	99.91	2.25
13	3.88	18.99	21.01	99.96	2.02
14	3.88	18.98	21.01	99.96	2.03
15	4.42	19.03	20.84	100.06	1.82
16	4.42	19.02	20.85	100.12	1.82
17	1.17	19.80	25.06	100.04	5.26
18	1.17	19.78	25.06	99.96	5.28

```
Tube Number:            89
File Name:              S089S1V2
Pressure Condition:     Vacuum
Steam Velocity:         2.0 (m/s)

Data     Vw      Tin     Tout      Ts      To-Ti
 #     (m/s)     (C)     (C)       (C)      (C)

 1      1.16    21.06   22.96    48.40     1.90
 2      1.16    21.06   22.96    48.49     1.90
 3      1.49    20.87   22.49    48.42     1.62
 4      1.49    20.87   22.49    48.42     1.62
 5      1.97    20.69   22.03    48.45     1.33
 6      1.97    20.69   22.03    48.45     1.33
 7      2.52    20.56   21.69    48.37     1.13
 8      2.52    20.56   21.69    48.35     1.13
 9      3.00    20.48   21.47    48.46      .99
10      3.00    20.49   21.48    48.50      .99
11      3.43    20.43   21.33    48.46      .90
12      3.43    20.43   21.33    48.64      .90
13      3.87    20.38   21.19    48.50      .80
14      3.87    20.38   21.19    48.60      .82
15      4.41    20.32   21.04    48.51      .72
16      4.41    20.33   21.04    48.51      .72
17      1.16    21.08   22.97    48.62     1.89
18      1.16    21.08   22.97    48.56     1.89
```

```
Tube Number:            89
File Name:              S089S1V3
Pressure Condition:     Vacuum
Steam Velocity:         2.0 (m/s)

Data     Vw      Tin     Tout      Ts      To-Ti
 #     (m/s)     (C)     (C)       (C)      (C)

 1      1.16    21.52   23.41    48.42     1.89
 2      1.16    21.52   23.40    48.47     1.89
 3      1.49    21.31   22.93    48.59     1.61
 4      1.49    21.32   22.93    48.46     1.61
 5      1.97    21.12   22.45    48.49     1.33
 6      1.97    21.12   22.45    48.36     1.33
 7      2.51    20.98   22.10    48.48     1.12
 8      2.51    20.98   22.10    48.37     1.13
 9      3.00    20.89   21.89    48.62      .99
10      3.43    20.84   21.73    48.30      .89
11      3.43    20.84   21.73    48.39      .89
12      3.86    20.79   21.60    48.49      .81
13      3.86    20.79   21.60    48.33      .80
14      4.41    20.74   21.46    48.43      .72
15      4.41    20.74   21.46    48.77      .72
16      1.16    21.51   23.38    48.48     1.87
17      1.16    21.51   23.38    48.45     1.87
```

Tube Number: 89
File Name: S089S1A3
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.26	26.86	100.00	5.60
2	1.16	21.26	26.86	99.86	5.60
3	1.49	21.05	25.79	100.01	4.74
4	1.49	21.05	25.79	100.07	4.74
5	1.97	20.86	24.75	100.02	3.89
6	1.97	20.86	24.74	99.96	3.89
7	2.52	20.72	24.00	100.04	3.28
8	2.52	20.71	24.00	100.04	3.28
9	3.00	20.63	23.51	99.98	2.88
10	3.00	20.63	23.51	100.09	2.88
11	3.43	20.57	23.13	100.12	2.56
12	3.43	20.57	23.12	100.03	2.55
13	3.87	20.52	22.88	99.93	2.36
14	3.87	20.52	22.88	99.80	2.36
15	4.41	20.46	22.55	99.94	2.08
16	4.41	20.46	22.55	100.01	2.08
17	1.16	21.31	27.20	99.86	5.88
18	1.16	21.32	27.20	99.87	5.88

Tube Number: 89
File Name: S089S1A4
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.25	26.87	100.00	5.62
2	1.16	21.25	26.87	99.98	5.62
3	1.49	21.04	25.86	99.89	4.81
4	1.49	21.04	25.84	99.86	4.80
5	1.97	20.86	24.80	99.92	3.95
6	1.97	20.85	24.81	100.02	3.95
7	2.52	20.72	24.03	100.01	3.31
8	2.52	20.72	24.02	100.02	3.30
9	3.00	20.64	23.53	99.94	2.89
10	3.00	20.63	23.53	99.95	2.89
11	3.43	20.57	23.16	100.08	2.59
12	3.43	20.57	23.16	99.99	2.58
13	3.87	20.53	22.87	100.04	2.34
14	3.87	20.53	22.87	99.95	2.34
15	4.41	20.47	22.58	99.89	2.10
16	4.41	20.47	22.58	99.93	2.10
17	1.16	21.27	26.92	100.00	5.65
18	1.16	21.27	26.90	99.93	5.63

Tube Number: 74
File Name: F074S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.13	23.32	48.29	2.19
2	1.16	21.14	23.32	48.21	2.18
3	1.49	20.92	22.78	48.19	1.86
4	1.49	20.92	22.77	48.20	1.85
5	1.87	20.78	22.40	48.07	1.62
6	1.87	20.78	22.41	48.69	1.62
7	2.24	20.67	22.10	48.09	1.43
8	2.24	20.67	22.10	48.12	1.43
9	2.62	20.59	21.88	48.19	1.29
10	2.62	20.60	21.88	48.03	1.29
11	3.00	20.53	21.71	48.66	1.18
12	3.00	20.53	21.71	48.23	1.18
13	3.38	20.48	21.56	48.17	1.08
14	3.38	20.48	21.56	48.68	1.08
15	3.65	20.45	21.46	48.73	1.01
16	3.65	20.44	21.46	48.73	1.02
17	1.16	21.18	23.38	48.01	2.20
18	1.16	21.19	23.40	47.98	2.21

Tube Number: 74
File Name: F074S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.18	23.36	48.81	2.17
2	1.16	21.18	23.36	48.15	2.18
3	1.49	20.98	22.85	48.65	1.87
4	1.49	20.98	22.85	48.62	1.87
5	1.87	20.81	22.43	48.62	1.61
6	1.87	20.81	22.41	48.12	1.60
7	2.24	20.71	22.15	48.48	1.44
8	2.24	20.71	22.14	48.75	1.43
9	2.62	20.63	21.92	48.05	1.29
10	2.62	20.63	21.91	48.66	1.28
11	3.00	20.56	21.73	48.02	1.17
12	3.00	20.56	21.73	48.79	1.17
13	3.38	20.51	21.59	48.71	1.08
14	3.38	20.51	21.59	48.58	1.08
15	3.65	20.48	21.50	48.03	1.02
16	3.65	20.48	21.50	48.12	1.02
17	1.16	21.21	23.38	48.26	2.17
18	1.16	21.22	23.38	48.79	2.17

Tube Number: 74
File Name: F074S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	20.26	27.48	99.99	7.22
2	1.17	20.25	27.47	99.83	7.22
3	1.49	20.02	26.20	99.80	6.18
4	1.49	20.02	26.20	99.79	6.18
5	1.87	19.85	25.21	100.04	5.35
6	1.87	19.85	25.21	99.94	5.36
7	2.25	19.73	24.50	100.08	4.76
8	2.25	19.73	24.49	99.98	4.76
9	2.63	19.65	23.95	99.85	4.30
10	2.63	19.65	23.95	100.10	4.31
11	3.01	19.58	23.49	100.01	3.91
12	3.01	19.58	23.49	99.85	3.92
13	3.39	19.52	23.14	100.22	3.62
14	3.39	19.52	23.14	99.79	3.62
15	3.66	19.48	22.91	100.08	3.43
16	3.66	19.48	22.91	100.12	3.43
17	1.17	20.23	27.55	99.81	7.32
18	1.17	20.23	27.56	100.06	7.34

Tube Number: 74
File Name: F074S1A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	20.23	27.58	99.92	7.35
2	1.17	20.22	27.58	100.06	7.35
3	1.49	20.00	26.33	100.12	6.33
4	1.49	20.00	26.33	99.97	6.33
5	1.87	19.84	25.33	100.14	5.49
6	1.87	19.84	25.33	100.12	5.49
7	2.25	19.72	24.59	100.03	4.87
8	2.25	19.72	24.60	99.93	4.88
9	2.63	19.64	24.03	100.19	4.40
10	2.63	19.64	24.04	100.07	4.40
11	3.01	19.57	23.59	99.73	4.02
12	3.01	19.57	23.60	99.65	4.03
13	3.39	19.52	23.21	99.75	3.69
14	3.39	19.52	23.21	100.08	3.69
15	3.66	19.49	22.98	100.09	3.49
16	3.66	19.49	22.98	99.94	3.49
17	1.17	20.25	27.61	100.18	7.36
18	1.17	20.25	27.62	99.93	7.37

Tube Number: 75
File Name: F075S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.80	22.88	48.78	2.08
2	1.16	20.80	22.88	48.19	2.08
3	1.49	20.61	22.41	48.22	1.80
4	1.49	20.61	22.41	48.23	1.80
5	1.87	20.47	22.00	48.07	1.54
6	1.87	20.47	22.00	48.58	1.53
7	2.25	20.38	21.72	48.71	1.34
8	2.25	20.39	21.73	48.77	1.34
9	2.62	20.32	21.52	48.77	1.21
10	2.62	20.31	21.52	48.24	1.21
11	3.00	20.26	21.36	48.63	1.09
12	3.00	20.27	21.35	48.79	1.09
13	3.38	20.23	21.22	48.06	.99
14	3.38	20.24	21.23	47.98	.99
15	3.65	20.23	21.16	48.62	.93
16	3.65	20.23	21.16	48.55	.92
17	1.16	20.97	23.04	48.59	2.07
18	1.16	20.98	23.04	48.68	2.06

Tube Number: 75
File Name: F075S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.05	23.11	48.30	2.06
2	1.16	21.06	23.13	48.17	2.07
3	1.49	20.86	22.64	48.42	1.78
4	1.49	20.86	22.63	48.34	1.77
5	1.87	20.72	22.25	48.67	1.52
6	1.87	20.73	22.25	48.13	1.52
7	2.24	20.65	21.98	48.30	1.33
8	2.24	20.66	21.98	48.72	1.33
9	2.62	20.59	21.78	48.62	1.19
10	2.62	20.59	21.79	48.72	1.20
11	3.00	20.54	21.61	48.30	1.07
12	3.00	20.54	21.62	48.80	1.08
13	3.38	20.51	21.50	48.30	.98
14	3.38	20.52	21.50	48.16	.99
15	3.65	20.49	21.42	48.25	.93
16	3.65	20.50	21.43	48.74	.93
17	1.16	21.21	23.28	48.31	2.06
18	1.16	21.23	23.28	48.65	2.05

Tube Number: 75
File Name: F075S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.32	28.57	99.84	7.25
2	1.16	21.32	28.57	100.02	7.25
3	1.49	21.11	27.36	99.84	6.25
4	1.49	21.11	27.36	100.12	6.25
5	1.87	20.95	26.38	99.99	5.43
6	1.87	20.95	26.38	99.91	5.43
7	2.24	20.84	25.69	100.06	4.84
8	2.24	20.85	25.70	99.94	4.85
9	2.62	20.77	25.17	99.96	4.40
10	2.62	20.77	25.17	99.94	4.40
11	3.00	20.71	24.77	100.02	4.05
12	3.00	20.71	24.77	99.94	4.06
13	3.38	20.67	24.43	99.89	3.76
14	3.38	20.67	24.43	100.04	3.76
15	3.65	20.64	24.21	100.10	3.57
16	3.65	20.64	24.22	100.12	3.58
17	1.16	21.33	28.70	100.13	7.37
18	1.16	21.35	28.73	100.16	7.38

Tube Number: 75
File Name: F075S1A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.42	28.70	99.88	7.28
2	1.16	21.42	28.70	99.89	7.28
3	1.49	21.22	27.56	99.95	6.34
4	1.49	21.22	27.55	99.82	6.33
5	1.87	21.07	26.59	99.88	5.53
6	1.87	21.07	26.59	99.93	5.53
7	2.24	20.97	25.90	100.10	4.93
8	2.24	20.97	25.91	99.97	4.94
9	2.62	20.89	25.35	99.80	4.47
10	2.62	20.89	25.36	100.00	4.47
11	3.00	20.84	24.96	99.99	4.12
12	3.00	20.84	24.96	100.05	4.11
13	3.38	20.80	24.60	100.02	3.80
14	3.38	20.80	24.60	100.09	3.80
15	3.65	20.77	24.39	99.93	3.61
16	3.65	20.77	24.39	99.93	3.62
17	1.16	21.51	28.87	99.98	7.37
18	1.16	21.51	28.89	100.13	7.38

Tube Number: 76
File Name: F076S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.62	23.79	48.37	2.16
2	1.16	21.63	23.79	48.58	2.16
3	1.49	21.45	23.31	48.51	1.86
4	1.49	21.45	23.31	48.28	1.86
5	1.86	21.32	22.92	48.58	1.60
6	1.86	21.32	22.91	48.57	1.60
7	2.24	21.24	22.66	48.64	1.42
8	2.24	21.25	22.66	48.35	1.42
9	2.62	21.18	22.45	48.66	1.27
10	2.62	21.18	22.44	48.29	1.26
11	3.00	21.13	22.29	48.16	1.16
12	3.00	21.14	22.29	48.70	1.15
13	3.38	21.09	22.15	48.20	1.05
14	3.38	21.09	22.14	48.66	1.05
15	3.65	21.08	22.07	48.80	.99
16	3.65	21.08	22.07	48.80	.99
17	1.16	21.81	23.92	48.52	2.11
18	1.16	21.82	23.93	48.04	2.11

Tube Number: 76
File Name: F076S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.89	23.99	48.27	2.10
2	1.16	21.89	24.00	48.59	2.11
3	1.49	21.70	23.51	48.52	1.81
4	1.49	21.71	23.51	48.54	1.80
5	1.86	21.58	23.13	48.32	1.56
6	1.86	21.58	23.13	48.28	1.55
7	2.24	21.47	22.84	48.58	1.38
8	2.24	21.48	22.85	48.53	1.37
9	2.62	21.40	22.64	48.28	1.24
10	2.62	21.40	22.64	48.54	1.23
11	3.00	21.34	22.47	48.55	1.13
12	3.00	21.35	22.48	48.33	1.13
13	3.38	21.31	22.35	48.50	1.04
14	3.38	21.31	22.34	48.49	1.04
15	3.65	21.27	22.25	48.38	.98
16	3.65	21.28	22.25	48.45	.98
17	1.16	21.99	24.07	48.45	2.08
18	1.16	21.99	24.07	48.57	2.08

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Tube Number:           76
File Name:             F076S1A1
Pressure Condition:    Atmospheric
Steam Velocity:        1.0 (m/s)

Data      Vw       Tin      Tout       Ts       To-Ti
 #      (m/s)      (C)       (C)       (C)       (C)

 1       1.16     22.45     30.09     99.81     7.64
 2       1.16     22.47     30.11    100.00     7.64
 3       1.49     22.29     29.02     99.81     6.73
 4       1.49     22.30     29.03    100.09     6.73
 5       1.86     22.15     28.09     99.82     5.93
 6       1.86     22.16     28.10    100.11     5.94
 7       2.24     22.06     27.40    100.12     5.34
 8       2.24     22.06     27.41    100.04     5.35
 9       2.62     21.99     26.87    100.07     4.88
10       2.62     21.99     26.88     99.80     4.89
11       3.00     21.94     26.46    100.08     4.52
12       3.00     21.94     26.47    100.14     4.53
13       3.37     21.92     26.13     99.75     4.20
14       3.37     21.92     26.15    100.03     4.23
15       3.64     21.89     25.93     99.97     4.04
16       3.64     21.89     25.94    100.24     4.04
17       1.16     22.62     30.21     99.95     7.58
18       1.16     22.62     30.20     99.79     7.58
```

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Tube Number:           76
File Name:             F076S1A2
Pressure Condition:    Atmospheric
Steam Velocity:        1.0 (m/s)

Data      Vw       Tin      Tout       Ts       To-Ti
 #      (m/s)      (C)       (C)       (C)       (C)

 1       1.16     22.66     30.35     99.92     7.69
 2       1.16     22.66     30.35     99.79     7.70
 3       1.48     22.45     29.17    100.09     6.72
 4       1.49     22.45     29.19    100.18     6.74
 5       1.86     22.29     28.22    100.08     5.93
 6       1.86     22.29     28.22     99.72     5.93
 7       2.24     22.18     27.51     99.79     5.33
 8       2.24     22.18     27.51     99.84     5.33
 9       2.62     22.10     26.95     99.88     4.85
10       2.62     22.10     26.95     99.89     4.85
11       3.00     22.03     26.52     99.78     4.48
12       3.00     22.03     26.52     99.69     4.48
13       3.37     21.98     26.14     99.78     4.16
14       3.37     21.98     26.14     99.93     4.16
15       3.64     21.94     25.90    100.01     3.96
16       3.64     21.94     25.91    100.11     3.97
17       1.16     22.64     30.42     99.81     7.78
18       1.16     22.65     30.44     99.90     7.80
```

Tube Number: 77
File Name: F077S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.46	29.39	99.86	6.93
2	1.16	22.46	29.40	100.05	6.94
3	1.49	22.24	28.19	100.00	5.95
4	1.49	22.23	28.19	99.89	5.96
5	1.86	22.09	27.34	99.80	5.24
6	1.86	22.09	27.34	99.79	5.25
7	2.24	21.98	26.71	99.90	4.73
8	2.24	21.98	26.70	100.08	4.73
9	2.62	21.89	26.22	100.09	4.33
10	2.62	21.89	26.22	100.11	4.33
11	3.00	21.82	25.80	99.98	3.98
12	3.00	21.82	25.80	99.96	3.98
13	3.37	21.77	25.48	99.89	3.71
14	3.37	21.76	25.48	99.89	3.72
15	3.64	21.72	25.17	100.06	3.44
16	3.64	21.72	25.19	99.91	3.46
17	1.16	22.44	29.50	99.86	7.06
18	1.16	22.44	29.50	99.94	7.06

Tube Number: 77
File Name: F077S1A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.42	29.43	99.96	7.01
2	1.16	22.42	29.43	99.85	7.01
3	1.49	22.22	28.33	99.85	6.12
4	1.49	22.22	28.33	99.88	6.12
5	1.86	22.05	27.39	100.00	5.33
6	1.86	22.05	27.39	99.97	5.34
7	2.24	21.94	26.74	99.98	4.80
8	2.24	21.94	26.74	99.86	4.80
9	2.62	21.86	26.22	99.92	4.36
10	2.62	21.85	26.21	99.90	4.36
11	3.00	21.79	25.81	99.91	4.03
12	3.00	21.79	25.82	99.85	4.03
13	3.37	21.73	25.47	99.81	3.74
14	3.37	21.73	25.47	99.93	3.74
15	3.64	21.69	25.27	99.91	3.58
16	3.64	21.69	25.28	99.93	3.59
17	1.16	22.42	29.53	99.89	7.12
18	1.16	22.42	29.52	99.79	7.10

Tube Number: 77
File Name: F077S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.11	24.18	48.61	2.06
2	1.16	22.12	24.18	48.64	2.06
3	1.49	21.92	23.70	48.56	1.77
4	1.49	21.92	23.70	48.18	1.77
5	1.86	21.80	23.33	48.21	1.54
6	1.86	21.80	23.33	48.23	1.53
7	2.24	21.69	23.04	48.72	1.35
8	2.24	21.68	23.03	48.21	1.35
9	2.62	21.63	22.85	48.22	1.22
10	2.62	21.63	22.86	48.18	1.22
11	3.00	21.59	22.71	48.16	1.12
12	3.00	21.58	22.70	48.50	1.12
13	3.37	21.53	22.56	48.45	1.03
14	3.37	21.54	22.56	48.69	1.02
15	3.64	21.52	22.49	48.72	.97
16	3.64	21.52	22.49	48.72	.98
17	1.16	22.24	24.28	48.72	2.04
18	1.16	22.24	24.28	48.73	2.05

Tube Number: 78
File Name: F078S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.23	23.40	48.18	2.17
2	1.16	21.24	23.42	48.29	2.17
3	1.49	21.07	22.95	48.69	1.88
4	1.49	21.07	22.95	48.67	1.88
5	1.87	20.93	22.57	48.67	1.64
6	1.87	20.94	22.58	48.57	1.64
7	2.24	20.85	22.29	48.26	1.44
8	2.24	20.86	22.30	48.24	1.44
9	2.62	20.79	22.08	48.25	1.29
10	2.62	20.79	22.09	48.48	1.29
11	3.00	20.74	21.92	48.67	1.19
12	3.00	20.74	21.93	48.71	1.19
13	3.38	20.70	21.80	48.18	1.10
14	3.38	20.70	21.80	48.20	1.10
15	3.65	20.67	21.71	48.59	1.03
16	3.65	20.67	21.71	48.03	1.03
17	1.16	21.37	23.52	48.67	2.16
18	1.16	21.37	23.54	48.71	2.16

Tube Number: 78
File Name: F078S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.40	23.54	48.39	2.14
2	1.16	21.40	23.55	48.21	2.15
3	1.49	21.20	23.04	48.69	1.84
4	1.49	21.20	23.05	48.65	1.85
5	1.87	21.05	22.67	48.67	1.62
6	1.87	21.04	22.66	48.21	1.62
7	2.24	20.94	22.36	48.26	1.42
8	2.24	20.94	22.37	48.59	1.43
9	2.62	20.86	22.16	48.37	1.30
10	2.62	20.86	22.16	48.75	1.30
11	3.00	20.79	21.98	48.24	1.19
12	3.00	20.79	21.98	48.61	1.19
13	3.38	20.74	21.83	48.67	1.10
14	3.38	20.73	21.83	48.23	1.09
15	3.65	20.70	21.74	48.19	1.04
16	3.65	20.70	21.74	48.67	1.04
17	1.16	21.39	23.53	48.33	2.14
18	1.16	21.39	23.55	48.53	2.16

Tube Number: 78
File Name: F078S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.05	28.03	99.77	6.98
2	1.16	21.04	28.04	100.11	6.99
3	1.49	20.84	26.87	99.73	6.03
4	1.49	20.84	26.85	100.03	6.01
5	1.87	20.68	25.84	100.01	5.16
6	1.87	20.67	25.83	100.02	5.16
7	2.25	20.57	25.19	99.98	4.62
8	2.25	20.56	25.19	99.82	4.63
9	2.62	20.48	24.65	100.01	4.18
10	2.62	20.48	24.65	100.10	4.18
11	3.00	20.41	24.21	100.03	3.80
12	3.00	20.41	24.23	100.01	3.82
13	3.38	20.36	23.89	99.92	3.53
14	3.38	20.36	23.90	99.95	3.54
15	3.65	20.32	23.68	99.90	3.36
16	3.65	20.32	23.68	99.76	3.36
17	1.16	21.03	28.00	99.90	6.97
18	1.16	21.03	28.00	100.10	6.97

Tube Number: 78
File Name: F078S1A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.03	28.03	100.05	7.01
2	1.16	21.03	28.03	100.06	7.01
3	1.49	20.83	26.87	100.02	6.05
4	1.49	20.82	26.88	99.89	6.05
5	1.87	20.67	25.93	100.05	5.26
6	1.87	20.66	25.94	100.08	5.28
7	2.25	20.56	25.27	99.93	4.71
8	2.25	20.56	25.27	100.13	4.71
9	2.62	20.47	24.72	100.12	4.25
10	2.62	20.47	24.73	100.05	4.26
11	3.00	20.40	24.29	99.83	3.89
12	3.00	20.40	24.29	99.95	3.89
13	3.38	20.34	23.95	100.03	3.60
14	3.38	20.34	23.95	100.13	3.61
15	3.65	20.31	23.74	99.91	3.43
16	3.65	20.31	23.73	99.84	3.43
17	1.16	21.01	28.01	99.81	7.00
18	1.16	21.01	28.01	99.79	7.00

Tube Number: 78
File Name: F078S1A3
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.19	28.18	99.94	6.99
2	1.16	21.20	28.22	99.85	7.02
3	1.49	21.03	27.09	99.99	6.06
4	1.49	21.03	27.09	99.93	6.06
5	1.87	20.89	26.17	99.95	5.28
6	1.87	20.89	26.18	100.07	5.29
7	2.25	20.76	25.49	99.99	4.72
8	2.25	20.76	25.50	99.93	4.74
9	2.62	20.66	24.95	100.04	4.29
10	2.62	20.66	24.96	100.11	4.30
11	3.00	20.57	24.48	99.98	3.91
12	3.00	20.56	24.46	99.90	3.89
13	3.38	20.49	24.09	100.04	3.60
14	3.38	20.48	24.10	100.08	3.61
15	3.65	20.43	23.86	99.90	3.43
16	3.65	20.43	23.86	99.90	3.44

Tube Number: 79
File Name: F079S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.38	23.51	48.62	2.13
2	1.16	21.38	23.50	48.59	2.12
3	1.49	21.17	23.00	48.66	1.83
4	1.49	21.17	23.02	48.15	1.84
5	1.87	21.02	22.60	48.19	1.58
6	1.87	21.02	22.60	48.54	1.58
7	2.24	20.91	22.31	48.55	1.40
8	2.24	20.91	22.31	48.61	1.40
9	2.62	20.82	22.07	48.73	1.25
10	2.62	20.82	22.08	48.50	1.26
11	3.00	20.76	21.91	48.16	1.15
12	3.00	20.76	21.91	48.72	1.15
13	3.38	20.71	21.77	48.58	1.06
14	3.38	20.70	21.76	48.20	1.06
15	3.65	20.66	21.65	48.20	.99
16	3.65	20.66	21.65	48.29	.99
17	1.16	21.32	23.46	48.43	2.14
18	1.16	21.36	23.49	48.16	2.13

Tube Number: 79
File Name: F079S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.11	28.00	100.08	6.89
2	1.16	21.11	28.04	100.21	6.93
3	1.49	20.89	26.81	100.15	5.92
4	1.49	20.89	26.80	99.95	5.91
5	1.87	20.74	25.87	99.82	5.13
6	1.87	20.73	25.87	99.95	5.14
7	2.25	20.62	25.18	100.02	4.56
8	2.25	20.62	25.18	100.05	4.56
9	2.62	20.54	24.64	99.86	4.11
10	2.62	20.53	24.63	99.78	4.10
11	3.00	20.46	24.22	100.07	3.75
12	3.00	20.46	24.22	99.85	3.76
13	3.38	20.42	23.93	99.85	3.52
14	3.38	20.42	23.94	99.86	3.52
15	3.65	20.38	23.68	99.83	3.30
16	3.65	20.37	23.68	99.81	3.31

Tube Number: 90
File Name: F090S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.39	25.50	48.24	2.11
2	1.16	23.39	25.50	48.62	2.11
3	1.48	23.20	25.03	48.25	1.83
4	1.48	23.20	25.03	48.73	1.84
5	1.86	23.05	24.66	48.61	1.61
6	1.86	23.05	24.66	48.59	1.61
7	2.24	22.95	24.38	48.30	1.43
8	2.24	22.95	24.38	48.23	1.42
9	2.61	22.88	24.16	48.22	1.28
10	2.61	22.88	24.15	48.54	1.28
11	2.99	22.82	23.99	48.66	1.17
12	2.99	22.82	23.99	48.30	1.17
13	3.37	22.77	23.85	48.29	1.08
14	3.37	22.77	23.83	48.25	1.06
15	3.64	22.74	23.76	48.50	1.01
16	3.64	22.74	23.76	48.39	1.01
17	1.16	23.42	25.53	48.63	2.11
18	1.16	23.43	25.54	48.70	2.11

Tube Number: 90
File Name: F090S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.46	25.57	48.30	2.10
2	1.16	23.47	25.58	48.64	2.11
3	1.48	23.28	25.11	48.65	1.83
4	1.86	23.13	24.73	48.66	1.60
5	1.86	23.14	24.72	48.62	1.59
6	2.24	23.04	24.46	48.67	1.42
7	2.24	23.04	24.46	48.71	1.42
8	2.61	22.97	24.25	48.57	1.28
9	2.61	22.97	24.26	48.41	1.29
10	2.99	22.91	24.08	48.67	1.17
11	2.99	22.92	24.09	48.50	1.17
12	3.37	22.87	23.94	48.58	1.07
13	3.37	22.87	23.94	48.48	1.07
14	3.64	22.84	23.85	48.53	1.01
15	3.64	22.84	23.85	48.37	1.01
16	1.16	23.52	25.61	48.53	2.10
17	1.16	23.52	25.62	48.43	2.10

```
Tube Number:            91
File Name:              F091S1V1
Pressure Condition: Vacuum
Steam Velocity:         2.0 (m/s)

Data     Vw       Tin      Tout       Ts        To-Ti
 #     (m/s)      (C)       (C)       (C)        (C)

 1      1.16     23.08    25.04     48.60      1.96
 2      1.16     23.09    25.06     48.65      1.96
 3      1.48     22.94    24.61     48.25      1.67
 4      1.48     22.94    24.61     48.58      1.67
 5      1.86     22.86    24.29     48.13      1.42
 6      1.86     22.87    24.29     48.77      1.42
 7      2.24     22.79    24.04     48.27      1.24
 8      2.24     22.80    24.04     48.33      1.24
 9      2.61     22.74    23.85     48.15      1.11
10      2.61     22.75    23.86     48.59      1.11
11      2.99     22.70    23.71     48.76      1.01
12      2.99     22.71    23.72     48.83      1.01
13      3.37     22.68    23.60     48.27       .92
14      3.37     22.68    23.60     48.08       .92
15      3.64     22.66    23.52     48.09       .85
16      3.64     22.67    23.53     48.11       .86
17      1.16     23.39    25.31     48.24      1.92
18      1.16     23.40    25.32     48.21      1.92
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Tube Number:            91
File Name:              F091S1V2
Pressure Condition: Vacuum
Steam Velocity:         2.0 (m/s)

Data     Vw       Tin      Tout       Ts        To-Ti
 #     (m/s)      (C)       (C)       (C)        (C)

 1      1.16     23.46    25.39     48.27      1.92
 2      1.16     23.46    25.39     48.35      1.93
 3      1.48     23.27    24.92     48.12      1.65
 4      1.48     23.28    24.93     48.05      1.65
 5      1.86     23.13    24.56     48.10      1.42
 6      1.86     23.13    24.55     48.42      1.42
 7      2.24     23.03    24.28     48.76      1.25
 8      2.24     23.03    24.28     48.49      1.24
 9      2.61     22.96    24.08     48.88      1.11
10      2.61     22.97    24.09     48.15      1.12
11      2.99     22.91    23.91     48.82      1.00
12      2.99     22.91    23.92     48.09      1.01
13      3.37     22.87    23.79     48.08       .92
14      3.37     22.86    23.78     48.15       .92
15      3.64     22.83    23.70     48.09       .86
16      3.64     22.83    23.69     48.01       .86
17      1.16     23.54    25.45     48.48      1.91
18      1.16     23.54    25.44     48.36      1.91
```

Tube Number: 92
File Name: F092S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.10	25.18	48.75	2.09
2	1.16	23.11	25.20	48.93	2.09
3	1.48	22.96	24.77	48.46	1.81
4	1.48	22.97	24.77	47.95	1.80
5	1.86	22.87	24.45	48.07	1.58
6	1.86	22.87	24.44	48.08	1.57
7	2.24	22.80	24.21	48.73	1.41
8	2.24	22.81	24.21	48.05	1.40
9	2.61	22.75	24.02	48.81	1.27
10	2.61	22.75	24.02	47.93	1.27
11	2.99	22.70	23.86	48.69	1.16
12	2.99	22.71	23.87	48.65	1.16
13	3.37	22.66	23.73	48.86	1.07
14	3.37	22.67	23.73	48.68	1.07
15	3.64	22.65	23.67	48.55	1.02
16	3.64	22.65	23.67	48.89	1.02
17	1.16	23.40	25.49	48.56	2.09
18	1.16	23.37	25.44	48.45	2.06

Tube Number: 92
File Name: F092S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.40	25.48	48.49	2.08
2	1.16	23.41	25.49	48.90	2.08
3	1.48	23.21	25.01	48.60	1.81
4	1.48	23.21	25.02	48.21	1.82
5	1.86	23.07	24.64	48.53	1.57
6	1.86	23.07	24.64	48.46	1.57
7	2.24	22.97	24.38	48.19	1.41
8	2.24	22.97	24.37	48.42	1.40
9	2.61	22.92	24.15	48.27	1.23
10	2.61	22.92	24.15	48.28	1.24
11	2.99	22.86	24.00	48.31	1.14
12	2.99	22.86	23.98	48.53	1.13
13	3.37	22.81	23.85	48.37	1.05
14	3.37	22.81	23.87	48.60	1.06
15	3.64	22.78	23.78	48.55	1.00
16	3.64	22.78	23.78	48.55	1.00
17	1.16	23.46	25.57	48.26	2.11
18	1.16	23.45	25.54	48.22	2.08

Tube Number: 93
File Name: F093S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.14	25.26	48.73	2.11
2	1.16	23.15	25.27	48.23	2.11
3	1.48	22.98	24.82	48.58	1.83
4	1.48	22.98	24.81	48.63	1.83
5	1.86	22.84	24.43	48.40	1.59
6	1.86	22.84	24.44	48.35	1.59
7	2.24	22.75	24.15	48.41	1.40
8	2.24	22.75	24.15	48.28	1.39
9	2.61	22.70	23.95	48.37	1.25
10	2.61	22.70	23.95	48.56	1.26
11	2.99	22.65	23.80	48.38	1.15
12	2.99	22.66	23.80	48.54	1.14
13	3.37	22.63	23.67	48.56	1.04
14	3.37	22.63	23.67	48.57	1.04
15	3.64	22.61	23.60	48.50	.99
16	3.64	22.61	23.60	48.58	.99
17	1.16	23.29	25.37	48.51	2.08
18	1.16	23.28	25.37	48.50	2.09

Tube Number: 93
File Name: F093S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.28	25.36	48.71	2.07
2	1.16	23.28	25.36	48.66	2.08
3	1.48	23.09	24.89	48.13	1.80
4	1.48	23.09	24.88	48.43	1.79
5	1.86	22.94	24.51	48.79	1.56
6	1.86	22.94	24.51	48.71	1.57
7	2.24	22.84	24.24	48.39	1.40
8	2.24	22.84	24.23	48.25	1.39
9	2.61	22.78	24.03	48.47	1.25
10	2.61	22.78	24.04	48.74	1.26
11	2.99	22.73	23.85	48.71	1.13
12	2.99	22.73	23.86	48.31	1.14
13	3.37	22.68	23.72	48.24	1.04
14	3.37	22.69	23.73	48.35	1.05
15	3.64	22.67	23.66	48.76	.99
16	3.64	22.67	23.65	48.35	.99
17	1.16	23.36	25.42	48.11	2.07
18	1.16	23.36	25.43	48.63	2.07

Tube Number: 94
File Name: F094S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.34	25.54	48.40	2.21
2	1.16	23.34	25.55	48.62	2.21
3	1.48	23.16	25.10	48.39	1.95
4	1.48	23.16	25.09	48.56	1.93
5	1.86	23.01	24.69	48.33	1.68
6	1.86	23.01	24.69	48.61	1.68
7	2.24	22.91	24.42	48.58	1.51
8	2.24	22.91	24.40	48.54	1.49
9	2.61	22.84	24.22	48.36	1.39
10	2.61	22.83	24.21	48.58	1.38
11	2.99	22.78	24.05	48.39	1.27
12	2.99	22.78	24.05	48.46	1.27
13	3.37	22.73	23.93	48.30	1.20
14	3.37	22.74	23.93	48.40	1.19
15	3.64	22.69	23.82	48.32	1.13
16	3.64	22.69	23.82	48.46	1.13
17	1.16	23.34	25.56	48.32	2.22
18	1.16	23.34	25.56	48.17	2.22

Tube Number: 94
File Name: F094S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.31	25.51	48.60	2.20
2	1.16	23.31	25.50	48.45	2.19
3	1.48	23.11	25.03	48.29	1.93
4	1.48	23.11	25.03	48.36	1.93
5	1.86	22.95	24.63	48.62	1.68
6	1.86	22.95	24.63	48.35	1.67
7	2.24	22.85	24.34	48.58	1.50
8	2.24	22.85	24.35	48.26	1.51
9	2.61	22.76	24.13	48.55	1.37
10	2.61	22.76	24.13	48.38	1.37
11	2.99	22.68	23.96	48.60	1.28
12	2.99	22.68	23.96	48.33	1.28
13	3.37	22.62	23.81	48.46	1.19
14	3.37	22.62	23.81	48.48	1.19
15	3.64	22.59	23.72	48.34	1.13
16	3.64	22.59	23.73	48.32	1.14
17	1.16	23.27	25.45	48.23	2.18
18	1.16	23.27	25.46	48.48	2.19

Tube Number: 95
File Name: F095S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.92	25.13	48.69	2.22
2	1.16	22.93	25.14	48.17	2.21
3	1.48	22.74	24.68	48.36	1.95
4	1.48	22.74	24.68	48.24	1.95
5	1.86	22.60	24.32	48.52	1.72
6	1.86	22.61	24.32	48.71	1.71
7	2.24	22.50	24.03	48.10	1.53
8	2.24	22.51	24.05	48.60	1.54
9	2.62	22.43	23.84	48.75	1.41
10	2.62	22.42	23.83	48.24	1.41
11	2.99	22.38	23.68	48.70	1.30
12	2.99	22.38	23.68	48.73	1.31
13	3.37	22.33	23.54	48.65	1.20
14	3.37	22.33	23.54	48.29	1.21
15	3.64	22.30	23.45	48.43	1.15
16	3.64	22.30	23.44	48.56	1.15
17	1.16	22.98	25.18	48.65	2.21
18	1.16	22.97	25.18	48.29	2.21

Tube Number: 95
File Name: F095S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.97	25.18	48.41	2.22
2	1.16	22.96	25.17	48.07	2.21
3	1.48	22.77	24.72	48.47	1.95
4	1.48	22.77	24.73	48.68	1.96
5	1.86	22.62	24.36	48.17	1.75
6	1.86	22.62	24.36	48.09	1.74
7	2.24	22.51	24.05	48.71	1.54
8	2.24	22.51	24.06	48.81	1.55
9	2.62	22.43	23.84	48.36	1.41
10	2.62	22.43	23.85	48.55	1.41
11	2.99	22.37	23.66	48.52	1.30
12	2.99	22.37	23.67	48.73	1.30
13	3.37	22.32	23.52	48.82	1.20
14	3.37	22.31	23.52	48.70	1.21
15	3.64	22.28	23.42	48.70	1.15
16	3.64	22.28	23.43	48.58	1.15
17	1.16	22.96	25.18	48.13	2.22
18	1.16	22.96	25.18	48.73	2.22

Tube Number: 90
File Name: F090S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.85	28.42	100.01	7.57
2	1.16	20.85	28.45	100.23	7.60
3	1.49	20.65	27.30	99.95	6.65
4	1.49	20.65	27.32	99.85	6.67
5	1.87	20.48	26.31	99.85	5.83
6	1.87	20.48	26.32	99.98	5.83
7	2.25	20.37	25.61	99.98	5.24
8	2.25	20.37	25.63	99.91	5.26
9	2.63	20.29	25.07	100.01	4.79
10	2.63	20.29	25.09	100.04	4.80
11	3.00	20.22	24.60	100.05	4.38
12	3.00	20.22	24.58	100.03	4.37
13	3.38	20.17	24.27	100.00	4.10
14	3.38	20.17	24.26	99.93	4.09
15	3.65	20.14	24.03	99.92	3.90
16	3.65	20.13	24.04	99.99	3.91

Tube Number: 91
File Name: F091S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.21	28.25	100.05	7.05
2	1.16	21.20	28.26	99.99	7.06
3	1.49	20.98	27.07	99.87	6.09
4	1.49	20.98	27.07	99.97	6.09
5	1.87	20.81	26.12	100.00	5.31
6	1.87	20.81	26.11	100.07	5.30
7	2.25	20.69	25.43	99.99	4.75
8	2.25	20.69	25.43	100.01	4.74
9	2.62	20.59	24.89	99.94	4.30
10	3.00	20.51	24.46	99.93	3.96
11	3.00	20.50	24.48	100.32	3.97
12	3.38	20.44	24.12	99.93	3.67
13	3.38	20.44	24.11	99.92	3.67
14	3.65	20.40	23.89	99.82	3.50
15	3.65	20.40	23.89	99.78	3.49
16	1.16	21.11	28.20	99.91	7.09

Tube Number: 92
File Name: F092S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.84	27.90	99.87	7.06
2	1.16	20.84	27.93	99.96	7.09
3	1.49	20.64	26.77	99.94	6.13
4	1.49	20.64	26.79	99.88	6.15
5	1.87	20.48	25.87	100.01	5.38
6	1.87	20.48	25.87	100.12	5.39
7	2.25	20.37	25.19	99.97	4.82
8	2.25	20.37	25.20	100.03	4.84
9	2.63	20.29	24.67	99.89	4.38
10	2.63	20.29	24.67	99.84	4.39
11	3.00	20.22	24.22	100.01	4.00
12	3.00	20.22	24.24	100.18	4.02
13	3.38	20.17	23.88	100.01	3.71
14	3.38	20.17	23.87	100.01	3.71
15	3.65	20.14	23.68	99.91	3.54
16	3.65	20.13	23.68	99.84	3.55

Tube Number: 93
File Name: F093S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.71	28.06	99.96	7.35
2	1.16	20.71	28.09	99.98	7.38
3	1.49	20.52	26.84	99.97	6.31
4	1.49	20.52	26.84	100.03	6.32
5	1.87	20.38	25.94	100.03	5.56
6	1.87	20.38	25.94	100.05	5.56
7	2.25	20.28	25.24	100.01	4.96
8	2.25	20.28	25.25	100.08	4.97
9	2.63	20.21	24.74	99.85	4.53
10	2.63	20.21	24.75	99.94	4.53
11	3.00	20.16	24.32	100.05	4.17
12	3.00	20.16	24.33	100.02	4.17
13	3.38	20.11	23.95	99.95	3.84
14	3.38	20.11	23.96	99.97	3.85
15	3.65	20.07	23.71	99.92	3.64
16	3.65	20.07	23.71	99.92	3.64
17	1.16	20.78	28.15	100.11	7.37
18	1.16	20.78	28.16	100.13	7.38

Tube Number: 94
File Name: F094S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.16	28.54	100.08	7.38
2	1.16	21.16	28.55	100.10	7.39
3	1.49	20.93	27.31	99.85	6.38
4	1.49	20.93	27.32	99.90	6.38
5	1.87	20.77	26.37	99.91	5.60
6	1.87	20.77	26.37	99.91	5.60
7	2.25	20.65	25.67	99.97	5.02
8	2.25	20.65	25.68	100.10	5.03
9	2.62	20.56	25.12	100.02	4.56
10	2.62	20.56	25.13	99.87	4.56
11	3.00	20.49	24.67	100.09	4.17
12	3.00	20.49	24.66	100.13	4.17
13	3.38	20.44	24.31	99.96	3.88
14	3.38	20.43	24.31	99.87	3.88
15	3.65	20.40	24.07	99.94	3.67
16	3.65	20.40	24.08	100.07	3.69
17	1.16	21.09	28.50	100.10	7.41
18	1.16	21.09	28.49	100.04	7.40

Tube Number: 95
File Name: F095S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.89	28.36	100.05	7.46
2	1.16	20.90	28.37	99.97	7.47
3	1.49	20.70	27.19	99.89	6.49
4	1.49	20.71	27.21	100.09	6.50
5	1.87	20.57	26.27	100.01	5.71
6	1.87	20.56	26.27	99.97	5.71
7	2.25	20.46	25.55	99.86	5.09
8	2.25	20.46	25.56	100.03	5.10
9	2.62	20.39	25.02	100.03	4.63
10	2.62	20.39	25.03	99.93	4.64
11	3.00	20.33	24.59	99.96	4.26
12	3.00	20.33	24.60	99.88	4.26
13	3.38	20.28	24.21	99.89	3.93
14	3.38	20.28	24.22	100.05	3.94
15	3.65	20.26	24.00	100.08	3.75
16	3.65	20.26	24.00	100.10	3.74
17	1.16	20.97	28.44	100.01	7.47
18	1.16	20.99	28.44	99.94	7.45

Tube Number: 86
File Name: F086S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.89	24.08	48.66	2.19
2	1.16	21.89	24.08	48.79	2.19
3	1.49	21.68	23.59	48.33	1.91
4	1.49	21.68	23.59	48.72	1.91
5	1.86	21.52	23.20	48.68	1.67
6	1.86	21.52	23.19	48.30	1.67
7	2.24	21.41	22.89	48.67	1.48
8	2.24	21.41	22.89	48.64	1.48
9	2.62	21.33	22.68	48.74	1.35
10	2.62	21.33	22.68	48.70	1.35
11	3.00	21.26	22.50	48.70	1.23
12	3.00	21.27	22.50	48.28	1.23
13	3.38	21.21	22.35	48.26	1.14
14	3.38	21.21	22.34	48.29	1.13
15	3.65	21.18	22.25	48.56	1.07
16	3.65	21.17	22.23	48.20	1.06
17	1.16	21.88	24.07	48.73	2.19
18	1.16	21.88	24.07	48.22	2.20

Tube Number: 86
File Name: F086S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.53	29.01	100.09	7.48
2	1.16	21.53	29.02	99.87	7.49
3	1.49	21.32	27.87	100.01	6.55
4	1.49	21.32	27.88	100.06	6.56
5	1.87	21.17	26.93	99.82	5.77
6	1.87	21.16	26.92	99.81	5.76
7	2.24	21.05	26.22	100.04	5.18
8	2.24	21.05	26.23	99.92	5.19
9	2.62	20.96	25.70	99.87	4.74
10	2.62	20.96	25.70	99.77	4.73
11	3.00	20.89	25.26	99.80	4.37
12	3.00	20.89	25.26	99.91	4.36
13	3.38	20.84	24.90	100.04	4.06
14	3.38	20.84	24.90	99.97	4.06
15	3.65	20.81	24.67	100.07	3.87
16	3.65	20.81	24.67	100.08	3.87
17	1.16	21.51	29.06	99.87	7.55
18	1.16	21.51	29.05	100.03	7.55

Tube Number: 86
File Name: F086S1A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.51	29.09	99.97	7.57
2	1.16	21.51	29.08	100.09	7.57
3	1.49	21.31	27.96	100.06	6.65
4	1.49	21.31	27.96	100.09	6.65
5	1.87	21.15	27.00	99.95	5.84
6	1.87	21.15	26.99	99.98	5.84
7	2.24	21.04	26.31	99.88	5.27
8	2.24	21.04	26.31	99.91	5.27
9	2.62	20.96	25.78	100.09	4.82
10	2.62	20.96	25.77	99.93	4.81
11	3.00	20.89	25.32	100.05	4.43
12	3.00	20.88	25.30	100.09	4.42
13	3.38	20.83	24.95	99.97	4.12
14	3.38	20.83	24.96	99.87	4.12
15	3.65	20.80	24.70	99.82	3.90
16	3.65	20.80	24.70	99.95	3.91
17	1.16	21.51	29.12	100.01	7.61
18	1.16	21.51	29.12	99.85	7.61

Tube Number: 06
File Name: F006S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.05	24.61	48.50	2.56
2	1.16	22.06	24.60	48.48	2.54
3	1.49	21.88	24.13	48.36	2.25
4	1.49	21.88	24.12	48.40	2.25
5	1.97	21.71	23.62	48.40	1.91
6	1.97	21.71	23.61	48.47	1.90
7	2.51	21.59	23.28	48.33	1.69
8	2.51	21.60	23.28	48.54	1.68
9	3.00	21.52	23.03	48.54	1.52
10	3.00	21.51	23.03	48.48	1.51
11	3.43	21.47	22.86	48.40	1.39
12	3.43	21.47	22.86	48.55	1.39
13	3.86	21.43	22.71	48.31	1.28
14	3.86	21.43	22.70	48.40	1.27
15	4.40	21.38	22.55	48.51	1.17
16	4.40	21.39	22.56	48.48	1.17
17	1.16	22.15	24.68	48.45	2.53
18	1.16	22.15	24.68	48.54	2.53

Tube Number: 06
File Name: F006S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.16	24.71	48.55	2.55
2	1.16	22.17	24.71	48.44	2.55
3	1.49	21.97	24.20	48.35	2.23
4	1.49	21.96	24.21	48.51	2.24
5	1.97	21.78	23.69	48.43	1.91
6	1.97	21.77	23.69	48.39	1.92
7	2.51	21.63	23.30	48.48	1.67
8	2.51	21.63	23.31	48.34	1.68
9	3.00	21.55	23.07	48.37	1.51
10	3.00	21.55	23.07	48.46	1.52
11	3.43	21.49	22.88	48.37	1.39
12	3.43	21.49	22.87	48.40	1.38
13	3.86	21.44	22.73	48.45	1.28
14	3.86	21.44	22.73	48.35	1.29
15	4.40	21.39	22.55	48.45	1.17
16	4.40	21.39	22.56	48.44	1.17
17	1.16	22.16	24.71	48.43	2.55
18	1.16	22.16	24.69	48.51	2.54

Tube Number: 96
File Name: F096S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.77	25.14	48.43	2.37
2	1.16	22.76	25.14	48.42	2.38
3	1.48	22.56	24.65	48.48	2.09
4	1.48	22.57	24.65	48.49	2.09
5	1.97	22.38	24.18	48.34	1.80
6	1.97	22.38	24.18	48.54	1.81
7	2.51	22.24	23.82	48.41	1.58
8	2.51	22.24	23.82	48.54	1.58
9	2.99	22.15	23.57	48.35	1.43
10	2.99	22.15	23.57	48.38	1.42
11	3.43	22.08	23.40	48.34	1.32
12	3.43	22.08	23.40	48.36	1.32
13	3.86	22.03	23.24	48.42	1.21
14	3.86	22.03	23.24	48.58	1.22
15	4.40	21.97	23.08	48.57	1.11
16	4.40	21.96	23.07	48.38	1.11
17	1.16	22.70	25.07	48.51	2.37
18	1.16	22.70	25.07	48.59	2.37

Tube Number: 96
File Name: F096SIV2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.67	25.05	48.63	2.38
2	1.16	22.67	25.06	48.25	2.39
3	1.48	22.47	24.58	48.43	2.10
4	1.48	22.47	24.58	48.36	2.11
5	1.97	22.28	24.08	48.29	1.81
6	1.97	22.28	24.08	48.46	1.80
7	2.51	22.15	23.73	48.53	1.58
8	2.51	22.15	23.73	48.51	1.58
9	2.99	22.07	23.50	48.34	1.43
10	2.99	22.07	23.51	48.26	1.44
11	3.43	22.00	23.33	48.50	1.32
12	3.43	22.00	23.32	48.25	1.32
13	3.86	21.94	23.17	48.50	1.23
14	3.86	21.93	23.17	48.64	1.23
15	4.40	21.88	23.01	48.56	1.13
16	4.40	21.88	23.00	48.44	1.12
17	1.16	22.63	25.00	48.51	2.37
18	1.16	22.63	25.00	48.19	2.37

Tube Number: 06
File Name: F006SIA1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.69	29.90	100.11	8.22
2	1.16	21.69	29.91	99.98	8.22
3	1.49	21.49	28.68	99.83	7.19
4	1.49	21.49	28.68	100.09	7.19
5	1.97	21.30	27.45	99.86	6.15
6	1.97	21.30	27.45	99.89	6.15
7	2.51	21.17	26.50	99.87	5.34
8	2.51	21.17	26.52	99.99	5.35
9	3.00	21.09	25.94	100.05	4.85
10	3.00	21.09	25.95	99.86	4.86
11	3.43	21.03	25.51	100.05	4.48
12	3.43	21.03	25.52	100.03	4.49
13	3.87	20.98	25.14	99.87	4.15
14	3.87	20.99	25.14	99.94	4.16
15	4.41	20.93	24.75	99.91	3.82
16	4.41	20.93	24.75	99.90	3.81
17	1.16	21.71	29.98	99.96	8.27
18	1.16	21.70	29.98	100.06	8.28

Tube Number: 06
File Name: F006S1A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.70	30.00	99.97	8.31
2	1.16	21.70	29.99	99.82	8.29
3	1.49	21.50	28.78	100.00	7.28
4	1.49	21.50	28.79	100.15	7.29
5	1.97	21.31	27.53	100.00	6.23
6	1.97	21.31	27.53	100.04	6.22
7	2.51	21.18	26.64	99.92	5.46
8	2.51	21.18	26.64	100.14	5.47
9	3.00	21.09	26.02	99.96	4.93
10	3.00	21.09	26.01	100.07	4.92
11	3.43	21.03	25.59	99.89	4.56
12	3.43	21.03	25.60	100.10	4.56
13	3.87	20.98	25.20	100.06	4.22
14	3.87	20.98	25.20	99.91	4.22
15	4.41	20.93	24.81	100.01	3.88
16	4.41	20.93	24.82	100.06	3.89
17	1.16	21.70	29.98	100.12	8.27
18	1.16	21.70	29.98	100.18	8.28

Tube Number: 96
File Name: F096S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.04	29.75	99.87	7.72
2	1.16	22.04	29.77	100.06	7.73
3	1.49	21.84	28.61	99.91	6.77
4	1.49	21.85	28.62	100.06	6.77
5	1.97	21.67	27.53	99.92	5.87
6	1.97	21.67	27.53	99.90	5.87
7	2.51	21.54	26.69	99.89	5.15
8	2.51	21.54	26.69	100.00	5.15
9	3.00	21.47	26.19	100.05	4.71
10	3.00	21.47	26.19	100.07	4.72
11	3.43	21.42	25.79	99.92	4.37
12	3.43	21.42	25.79	99.94	4.37
13	3.86	21.38	25.45	100.01	4.07
14	3.86	21.38	25.46	99.88	4.08
15	4.40	21.33	25.09	99.87	3.77
16	4.40	21.33	25.10	99.87	3.77
17	1.16	22.09	29.81	100.07	7.72
18	1.16	22.09	29.81	100.07	7.72

Tube Number: 96
File Name: F096S1A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.11	29.85	99.87	7.74
2	1.16	22.11	29.86	99.91	7.74
3	1.49	21.91	28.66	99.89	6.76
4	1.49	21.90	28.67	99.97	6.76
5	1.97	21.72	27.54	100.00	5.83
6	1.97	21.71	27.54	99.91	5.82
7	2.51	21.58	26.72	99.93	5.14
8	2.51	21.58	26.73	100.07	5.15
9	3.00	21.51	26.20	99.85	4.70
10	3.00	21.51	26.20	99.86	4.69
11	3.43	21.45	25.79	100.02	4.34
12	3.43	21.45	25.79	99.93	4.34
13	3.86	21.40	25.43	99.90	4.03
14	3.86	21.40	25.44	100.00	4.04
15	4.40	21.35	25.06	100.06	3.71
16	4.40	21.35	25.07	100.05	3.71
17	1.16	22.12	29.87	99.93	7.75
18	1.16	22.12	29.87	100.06	7.75

Tube Number: 83
File Name: F083S1V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.49	25.11	48.35	2.62
2	1.16	22.49	25.10	48.61	2.61
3	1.48	22.31	24.62	48.20	2.31
4	1.48	22.31	24.62	48.62	2.31
5	1.97	22.13	24.14	48.25	2.00
6	1.97	22.13	24.14	48.65	2.01
7	2.51	22.01	23.76	48.20	1.75
8	2.51	22.01	23.77	48.63	1.76
9	3.00	21.94	23.54	48.65	1.60
10	3.00	21.93	23.53	48.29	1.60
11	3.43	21.88	23.36	48.63	1.48
12	3.43	21.87	23.35	48.28	1.48
13	3.86	21.82	23.19	48.23	1.37
14	3.86	21.82	23.19	48.26	1.37
15	4.40	21.77	23.02	48.59	1.26
16	4.40	21.77	23.03	48.58	1.26
17	1.16	22.49	25.14	48.49	2.65
18	1.16	22.51	25.17	48.50	2.66

Tube Number: 83
File Name: F083S1V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.56	25.24	48.29	2.68
2	1.16	22.56	25.25	48.53	2.69
3	1.48	22.37	24.70	48.53	2.33
4	1.48	22.36	24.69	48.52	2.33
5	1.97	22.21	24.23	48.29	2.02
6	1.97	22.20	24.23	48.32	2.02
7	2.51	22.10	23.88	48.43	1.78
8	2.51	22.10	23.88	48.47	1.79
9	3.00	22.02	23.64	48.51	1.62
10	2.99	22.03	23.65	48.62	1.62
11	3.43	21.97	23.46	48.59	1.48
12	3.43	21.98	23.47	48.38	1.48
13	3.86	21.95	23.33	48.52	1.38
14	3.86	21.95	23.32	48.56	1.38
15	4.40	21.90	23.16	48.56	1.26
16	4.40	21.91	23.17	48.41	1.26
17	1.16	22.67	25.33	48.49	2.66
18	1.16	22.67	25.35	48.50	2.67

Tube Number: 83
File Name: F083S1A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.61	30.96	99.97	8.35
2	1.16	22.61	30.98	99.89	8.36
3	1.49	22.42	29.70	99.96	7.28
4	1.49	22.43	29.71	100.02	7.28
5	1.97	22.25	28.48	99.87	6.23
6	1.97	22.25	28.48	100.00	6.23
7	2.51	22.14	27.62	99.96	5.48
8	2.51	22.14	27.62	99.93	5.48
9	3.00	22.07	27.04	100.02	4.97
10	3.00	22.07	27.04	99.95	4.97
11	3.43	22.02	26.61	100.02	4.59
12	3.43	22.02	26.61	99.98	4.59
13	3.86	21.98	26.25	99.95	4.27
14	3.86	21.98	26.25	99.96	4.27
15	4.40	21.94	25.86	99.99	3.93
16	4.40	21.94	25.86	99.95	3.92
17	1.16	22.70	31.01	99.93	8.31
18	1.16	22.71	31.03	100.14	8.32

Tube Number: 83
File Name: F083S1A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.74	31.10	100.02	8.36
2	1.16	22.74	31.09	100.01	8.35
3	1.48	22.54	29.81	100.02	7.27
4	1.48	22.54	29.80	100.03	7.27
5	1.97	22.36	28.68	99.89	6.32
6	1.97	22.36	28.66	99.96	6.30
7	2.51	22.22	27.76	100.01	5.53
8	2.51	22.22	27.75	99.96	5.53
9	3.00	22.14	27.13	99.89	4.99
10	3.00	22.13	27.11	99.94	4.97
11	3.43	22.08	26.70	100.00	4.62
12	3.43	22.08	26.70	100.10	4.62
13	3.86	22.03	26.32	99.97	4.29
14	3.86	22.03	26.32	99.92	4.29
15	4.40	21.98	25.92	99.87	3.94
16	4.40	21.98	25.92	99.88	3.94
17	1.16	22.75	31.08	100.02	8.33
18	1.16	22.74	31.05	100.03	8.31

Tube Number: 88
File Name: S088S0V3
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	19.87	21.18	48.51	1.31
2	1.17	19.86	21.19	48.56	1.32
3	1.49	19.65	20.81	48.31	1.16
4	1.87	19.49	20.50	48.58	1.01
5	1.87	19.49	20.49	48.72	1.01
6	2.25	19.38	20.28	48.31	.90
7	2.25	19.38	20.28	48.40	.90
8	2.63	19.30	20.10	48.32	.80
9	2.63	19.30	20.11	48.49	.80
10	3.01	19.24	19.97	48.58	.72
11	3.01	19.24	19.97	48.54	.73
12	3.39	19.19	19.86	48.54	.67
13	3.39	19.19	19.85	48.33	.66
14	3.66	19.16	19.79	48.54	.63
15	3.66	19.16	19.79	48.35	.63
16	1.17	19.86	21.18	48.56	1.33

Tube Number: 88
File Name: S088S0A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	19.63	23.42	100.04	3.79
2	1.17	19.62	23.42	99.98	3.79
3	1.49	19.40	22.63	99.94	3.24
4	1.49	19.39	22.63	99.80	3.24
5	1.87	19.22	22.00	100.09	2.78
6	1.87	19.22	22.01	99.97	2.79
7	2.25	19.09	21.54	99.91	2.45
8	2.25	19.09	21.53	100.00	2.44
9	2.63	19.01	21.19	99.98	2.19
10	2.63	19.01	21.19	99.90	2.18
11	3.01	18.94	20.92	99.95	1.98
12	3.01	18.94	20.92	99.91	1.98
13	3.39	18.89	20.70	99.88	1.81
14	3.39	18.89	20.69	99.99	1.80
15	3.66	18.86	20.55	99.94	1.69
16	3.66	18.86	20.54	99.85	1.69
17	1.17	19.58	23.37	99.87	3.80
18	1.17	19.58	23.38	99.81	3.80

Tube Number: 01
File Name: S001S0V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	4.41	19.52	20.09	48.48	.58
2	4.41	19.50	20.08	48.50	.58
3	3.87	19.46	20.10	48.35	.64
4	3.87	19.44	20.08	48.32	.64
5	3.44	19.38	20.06	48.47	.68
6	3.44	19.37	20.06	48.55	.69
7	3.01	19.34	20.10	48.40	.76
8	3.01	19.33	20.10	48.34	.77
9	2.52	19.36	20.21	48.39	.85
10	2.52	19.36	20.21	48.49	.85
11	1.98	19.46	20.45	48.50	.99
12	1.98	19.46	20.44	48.45	.99
13	1.49	19.64	20.75	48.45	1.11
14	1.49	19.65	20.74	48.42	1.10
15	1.17	19.84	21.09	48.46	1.25
16	1.17	19.84	21.10	48.40	1.26

Tube Number: 01
File Name: S001S0A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.17	19.78	23.76	100.02	3.98
2	1.17	19.78	23.81	99.91	4.02
3	1.49	19.56	22.85	100.01	3.29
4	1.49	19.56	22.86	99.91	3.31
5	1.98	19.37	22.17	99.92	2.80
6	1.98	19.37	22.16	99.89	2.80
7	2.52	19.23	21.62	100.01	2.39
8	2.52	19.23	21.63	99.98	2.40
9	3.01	19.15	21.28	99.98	2.13
10	3.01	19.15	21.29	100.00	2.14
11	3.44	19.10	21.03	100.00	1.94
12	3.44	19.10	21.06	100.01	1.96
13	3.88	19.05	20.86	99.92	1.80
14	3.88	19.05	20.85	99.90	1.80
15	4.42	19.00	20.63	99.89	1.63
16	4.42	19.00	20.63	99.86	1.63
17	1.17	19.76	23.66	99.95	3.91
18	1.17	19.76	23.68	100.04	3.92

Tube Number: 89
File Name: S089S0V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.17	22.49	48.50	1.32
2	1.16	21.17	22.49	48.44	1.32
3	1.49	20.97	22.14	48.59	1.17
4	1.49	20.99	22.16	48.48	1.18
5	1.97	20.80	21.82	48.44	1.01
6	1.97	20.80	21.82	48.51	1.02
7	2.51	20.69	21.58	48.37	.89
8	2.51	20.68	21.57	48.30	.88
9	3.00	20.61	21.40	48.49	.79
10	3.00	20.61	21.40	48.42	.79
11	3.43	20.57	21.29	48.48	.72
12	3.43	20.57	21.30	48.36	.73
13	3.87	20.53	21.20	48.62	.68
14	3.87	20.53	21.21	48.58	.68
15	4.41	20.49	21.11	48.48	.62
16	4.41	20.49	21.11	48.56	.62
17	1.16	21.24	22.54	48.24	1.30
18	1.16	21.24	22.55	48.65	1.30

Tube Number: 89
File Name: S089S0V5
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.71	23.01	48.55	1.31
2	1.16	21.71	23.01	48.54	1.30
3	1.49	21.49	22.65	48.52	1.16
4	1.49	21.48	22.64	48.39	1.16
5	1.97	21.29	22.30	48.40	1.01
6	1.97	21.29	22.30	48.49	1.01
7	2.51	21.15	22.03	48.51	.88
8	2.51	21.15	22.03	48.47	.88
9	3.00	21.08	21.87	48.49	.79
10	3.00	21.08	21.87	48.37	.79
11	3.43	21.01	21.74	48.41	.73
12	3.43	21.00	21.74	48.44	.73
13	3.86	20.95	21.63	48.37	.68
14	3.86	20.95	21.62	48.53	.68
15	4.40	20.88	21.49	48.28	.61
16	4.40	20.88	21.49	48.39	.61
17	1.16	21.58	22.88	48.40	1.29
18	1.16	21.58	22.88	48.32	1.30

Tube Number: 74
File Name: F074S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.25	22.80	48.06	1.55
2	1.16	21.25	22.79	48.09	1.55
3	1.49	21.04	22.42	47.97	1.38
4	1.49	21.04	22.42	48.38	1.38
5	1.87	20.88	22.13	48.04	1.24
6	1.87	20.88	22.12	48.09	1.24
7	2.24	20.78	21.91	48.75	1.13
8	2.24	20.78	21.90	48.63	1.12
9	2.62	20.71	21.75	48.10	1.03
10	2.62	20.71	21.74	48.74	1.03
11	3.00	20.66	21.61	48.61	.95
12	3.00	20.66	21.61	48.67	.95
13	3.38	20.61	21.50	48.68	.88
14	3.38	20.62	21.50	48.09	.88
15	3.65	20.59	21.43	48.18	.84
16	3.65	20.60	21.43	48.79	.84
17	1.16	21.30	22.86	48.00	1.56
18	1.16	21.30	22.85	48.75	1.56

Tube Number: 75
File Name: F075S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.34	22.86	48.69	1.53
2	1.16	21.33	22.85	48.80	1.51
3	1.49	21.14	22.50	48.61	1.36
4	1.49	21.13	22.49	48.71	1.35
5	1.87	20.99	22.20	48.67	1.21
6	1.87	20.99	22.20	48.57	1.21
7	2.24	20.89	21.98	48.30	1.09
8	2.24	20.89	21.97	48.58	1.08
9	2.62	20.82	21.81	48.74	.99
10	2.62	20.82	21.81	48.79	.99
11	3.00	20.77	21.69	48.27	.92
12	3.00	20.77	21.68	48.64	.91
13	3.38	20.73	21.57	48.21	.84
14	3.38	20.73	21.57	48.34	.84
15	3.65	20.70	21.50	48.78	.79
16	3.65	20.71	21.51	48.30	.80
17	1.16	21.37	22.86	48.62	1.49
18	1.16	21.37	22.86	48.09	1.49

Tube Number: 76
File Name: F076S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.10	23.60	48.31	1.50
2	1.16	22.10	23.60	48.12	1.50
3	1.49	21.92	23.28	48.65	1.35
4	1.49	21.92	23.27	48.25	1.35
5	1.86	21.77	22.96	48.52	1.19
6	1.86	21.77	22.97	48.56	1.20
7	2.24	21.68	22.78	48.53	1.10
8	2.24	21.68	22.78	48.56	1.10
9	2.62	21.60	22.61	48.33	1.01
10	2.62	21.61	22.61	48.28	1.00
11	3.00	21.56	22.49	48.34	.92
12	3.00	21.56	22.48	48.43	.92
13	3.37	21.54	22.39	48.45	.85
14	3.37	21.54	22.40	48.34	.85
15	3.64	21.53	22.34	48.43	.81
16	3.64	21.53	22.34	48.34	.81
17	1.16	22.30	23.82	48.22	1.53
18	1.16	22.31	23.82	48.45	1.52

Tube Number: 77
File Name: F077S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.29	23.78	48.25	1.50
2	1.16	22.28	23.77	48.59	1.50
3	1.48	22.08	23.38	48.21	1.31
4	1.48	22.08	23.39	48.16	1.32
5	1.86	21.93	23.11	48.35	1.18
6	1.86	21.93	23.11	48.70	1.18
7	2.24	21.83	22.90	48.72	1.07
8	2.24	21.82	22.89	48.36	1.07
9	2.62	21.74	22.73	48.65	.98
10	2.62	21.74	22.72	48.76	.97
11	3.00	21.69	22.59	48.36	.90
12	3.00	21.69	22.59	48.28	.90
13	3.37	21.64	22.47	48.23	.83
14	3.37	21.64	22.47	48.12	.83
15	3.64	21.61	22.41	48.06	.79
16	3.64	21.62	22.41	48.15	.79
17	1.16	22.26	23.74	48.71	1.48
18	1.16	22.27	23.75	48.38	1.48

Tube Number: 78
File Name: F078S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.34	22.92	48.74	1.58
2	1.16	21.34	22.91	48.33	1.58
3	1.49	21.14	22.52	48.65	1.38
4	1.49	21.14	22.52	48.49	1.38
5	1.87	20.97	22.20	48.58	1.22
6	1.87	20.97	22.20	48.68	1.22
7	2.24	20.88	21.99	48.27	1.11
8	2.24	20.87	21.99	48.30	1.11
9	2.62	20.81	21.83	48.23	1.03
10	2.62	20.81	21.83	48.36	1.03
11	3.00	20.74	21.69	48.20	.95
12	3.00	20.74	21.66	48.11	.92
13	3.38	20.69	21.56	48.62	.87
14	3.38	20.70	21.56	48.63	.86
15	3.65	20.67	21.50	48.78	.84
16	1.16	21.28	22.86	48.46	1.58
17	1.16	21.32	22.91	48.25	1.58
18	1.16	21.35	22.95	48.84	1.60

Tube Number: 79
File Name: F079S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.38	22.93	48.65	1.55
2	1.16	21.38	22.94	48.21	1.56
3	1.49	21.18	22.55	48.20	1.37
4	1.49	21.17	22.55	48.17	1.37
5	1.87	21.04	22.27	48.58	1.23
6	1.87	21.04	22.26	48.64	1.22
7	2.24	20.93	22.04	48.70	1.11
8	2.24	20.93	22.05	48.26	1.11
9	2.62	20.86	21.89	48.46	1.02
10	2.62	20.86	21.88	48.33	1.02
11	3.00	20.80	21.74	48.57	.94
12	3.00	20.80	21.75	48.65	.95
13	3.38	20.76	21.64	48.56	.88
14	3.38	20.76	21.63	48.60	.87
15	3.65	20.73	21.56	48.15	.83
16	3.65	20.73	21.55	48.10	.82
17	1.16	21.35	22.91	48.63	1.56
18	1.16	21.40	22.95	48.70	1.55

Tube Number: 90
File Name: F090S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.56	25.05	48.33	1.49
2	1.16	23.56	25.06	48.65	1.50
3	1.48	23.36	24.70	48.76	1.34
4	1.48	23.37	24.70	48.39	1.33
5	1.86	23.22	24.43	48.52	1.21
6	1.86	23.22	24.42	48.37	1.20
7	2.24	23.12	24.22	48.21	1.09
8	2.24	23.12	24.21	48.12	1.09
9	2.61	23.05	24.06	48.48	1.01
10	2.61	23.05	24.06	48.56	1.01
11	2.99	22.99	23.93	48.61	.93
12	2.99	23.00	23.93	48.43	.94
13	3.37	22.95	23.83	48.55	.88
14	3.37	22.96	23.83	48.41	.88
15	3.64	22.94	23.77	48.57	.83
16	3.64	22.93	23.76	48.09	.83
17	1.16	23.56	25.05	48.70	1.49
18	1.16	23.58	25.06	48.69	1.49

Tube Number: 91
File Name: F091S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.58	25.00	48.04	1.42
2	1.16	23.58	25.00	48.64	1.42
3	1.48	23.38	24.63	48.84	1.25
4	1.48	23.38	24.63	48.18	1.25
5	1.86	23.23	24.35	48.89	1.11
6	1.86	23.23	24.34	48.58	1.11
7	2.24	23.14	24.14	48.09	1.00
8	2.24	23.14	24.14	48.13	1.00
9	2.61	23.07	23.98	48.75	.92
10	2.61	23.07	23.98	48.74	.91
11	2.99	23.01	23.85	48.69	.84
12	2.99	23.01	23.85	48.90	.83
13	3.37	22.96	23.74	48.70	.77
14	3.37	22.97	23.74	48.10	.78
15	3.64	22.94	23.67	48.20	.73
16	3.64	22.94	23.67	48.69	.73
17	1.16	23.60	25.01	48.09	1.40
18	1.16	23.60	25.00	48.21	1.40

Tube Number: 92
File Name: F092S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.49	24.95	48.46	1.46
2	1.16	23.49	24.95	48.71	1.46
3	1.48	23.29	24.58	48.70	1.29
4	1.48	23.29	24.58	48.68	1.29
5	1.86	23.14	24.30	48.52	1.16
6	1.86	23.14	24.30	48.61	1.16
7	2.24	23.05	24.10	48.45	1.05
8	2.24	23.05	24.10	48.39	1.05
9	2.61	22.98	23.95	48.65	.98
10	2.61	22.98	23.95	48.67	.97
11	2.99	22.91	23.82	48.30	.90
12	2.99	22.92	23.81	48.62	.90
13	3.37	22.88	23.73	48.30	.85
14	3.37	22.88	23.72	48.61	.84
15	3.64	22.85	23.65	48.23	.81
16	3.64	22.84	23.65	48.27	.80
17	1.16	23.51	24.98	48.43	1.47
18	1.16	23.51	24.97	48.46	1.46

Tube Number: 93
File Name: F093S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.53	25.03	48.77	1.50
2	1.16	23.53	25.02	48.23	1.49
3	1.48	23.38	24.68	48.22	1.30
4	1.48	23.38	24.69	48.24	1.31
5	1.86	23.26	24.43	48.62	1.17
6	1.86	23.26	24.43	48.58	1.17
7	2.24	23.18	24.23	48.57	1.05
8	2.24	23.18	24.23	48.27	1.05
9	2.61	23.12	24.08	48.62	.96
10	2.61	23.12	24.08	48.49	.96
11	2.99	23.08	23.97	48.61	.88
12	2.99	23.09	23.97	48.61	.88
13	3.37	23.05	23.88	48.41	.83
14	3.37	23.05	23.88	48.62	.83
15	3.64	23.03	23.81	48.62	.78
16	3.64	23.03	23.81	48.55	.78
17	1.16	23.68	25.17	48.82	1.48
18	1.16	23.68	25.15	48.69	1.47

Tube Number: 94
File Name: F094S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	23.28	24.82	48.04	1.54
2	1.16	23.28	24.82	48.84	1.54
3	1.48	23.09	24.45	48.90	1.36
4	1.48	23.08	24.44	48.80	1.36
5	1.86	22.94	24.16	47.97	1.22
6	1.86	22.94	24.16	48.04	1.22
7	2.24	22.83	23.95	48.41	1.12
8	2.24	22.83	23.95	48.70	1.12
9	2.61	22.75	23.80	48.34	1.05
10	2.61	22.75	23.80	48.36	1.05
11	2.99	22.70	23.68	48.53	.98
12	2.99	22.70	23.68	48.52	.98
13	3.37	22.65	23.57	48.42	.92
14	3.37	22.65	23.56	48.52	.91
15	3.64	22.62	23.50	48.29	.87
16	3.64	22.63	23.50	48.52	.87
17	1.16	23.26	24.80	48.18	1.54
18	1.16	23.26	24.80	48.13	1.54

Tube Number: 95
File Name: F095S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.96	24.51	48.39	1.54
2	1.16	22.96	24.50	48.13	1.54
3	1.48	22.78	24.17	48.16	1.39
4	1.48	22.78	24.17	48.68	1.39
5	1.86	22.62	23.85	48.13	1.23
6	1.86	22.62	23.86	48.19	1.24
7	2.24	22.52	23.66	48.25	1.13
8	2.24	22.52	23.66	48.71	1.14
9	2.62	22.45	23.51	48.81	1.06
10	2.62	22.45	23.50	48.18	1.05
11	2.99	22.39	23.37	48.22	.98
12	2.99	22.38	23.37	48.66	.99
13	3.37	22.34	23.27	48.32	.93
14	3.37	22.34	23.27	48.32	.93
15	3.64	22.31	23.19	48.58	.89
16	3.64	22.31	23.20	48.11	.89
17	1.16	22.95	24.49	48.85	1.55
18	1.16	22.97	24.53	48.21	1.56

Tube Number: 74
File Name: F074S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.60	25.78	100.12	5.18
2	1.16	20.59	25.77	99.77	5.18
3	1.49	20.34	24.83	100.20	4.49
4	1.49	20.34	24.83	99.99	4.49
5	1.87	20.16	24.11	100.13	3.95
6	1.87	20.16	24.10	99.82	3.94
7	2.25	20.04	23.61	99.79	3.57
8	2.25	20.04	23.61	99.74	3.57
9	2.63	19.95	23.21	99.77	3.26
10	2.63	19.95	23.22	99.74	3.27
11	3.01	19.88	22.94	100.06	3.06
12	3.01	19.87	22.94	99.82	3.07
13	3.38	19.79	22.67	99.66	2.88
14	3.38	19.79	22.66	99.72	2.87
15	3.66	19.73	22.47	100.30	2.74
16	3.66	19.73	22.46	100.24	2.74
17	1.16	20.39	25.62	99.83	5.23
18	1.16	20.39	25.63	99.91	5.25

Tube Number: 74
File Name: F074S0A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.35	25.60	100.10	5.25
2	1.16	20.34	25.61	99.79	5.27
3	1.49	20.12	24.67	99.99	4.55
4	1.49	20.12	24.69	100.01	4.58
5	1.87	19.95	23.99	99.78	4.05
6	1.87	19.94	24.00	99.75	4.05
7	2.25	19.82	23.49	99.89	3.67
8	2.25	19.82	23.49	99.93	3.68
9	2.63	19.73	23.09	100.04	3.36
10	2.63	19.73	23.11	99.93	3.37
11	3.01	19.67	22.79	100.02	3.12
12	3.01	19.67	22.79	100.02	3.12
13	3.39	19.62	22.51	99.94	2.89
14	3.39	19.62	22.51	99.85	2.90
15	3.66	19.58	22.34	99.80	2.76
16	3.66	19.58	22.34	99.99	2.75
17	1.17	20.29	25.68	100.03	5.39
18	1.17	20.29	25.68	99.97	5.38

Tube Number: 75
File Name: F075S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.52	26.57	99.90	5.06
2	1.16	21.51	26.59	100.02	5.08
3	1.49	21.30	25.79	100.05	4.49
4	1.49	21.30	25.78	99.86	4.48
5	1.87	21.14	25.15	100.08	4.01
6	1.87	21.13	25.15	99.98	4.02
7	2.24	21.03	24.70	99.98	3.68
8	2.24	21.03	24.70	99.78	3.67
9	2.62	20.94	24.33	100.00	3.39
10	2.62	20.94	24.33	100.00	3.39
11	3.00	20.88	24.05	99.89	3.16
12	3.00	20.88	24.05	100.03	3.17
13	3.38	20.83	23.79	99.86	2.96
14	3.38	20.83	23.79	100.00	2.96
15	3.65	20.80	23.62	100.02	2.83
16	3.65	20.80	23.63	99.98	2.83
17	1.16	21.48	26.58	99.94	5.10
18	1.16	21.49	26.56	99.91	5.08

Tube Number: 76
File Name: F076S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.68	28.07	100.09	5.39
2	1.16	22.68	28.07	99.98	5.39
3	1.48	22.48	27.24	99.88	4.76
4	1.48	22.47	27.23	100.01	4.75
5	1.86	22.32	26.60	100.01	4.28
6	1.86	22.32	26.59	100.12	4.27
7	2.24	22.22	26.13	100.11	3.92
8	2.24	22.22	26.15	100.06	3.94
9	2.62	22.14	25.78	100.04	3.64
10	2.62	22.14	25.78	100.01	3.64
11	3.00	22.08	25.50	100.01	3.42
12	3.00	22.08	25.51	99.90	3.43
13	3.37	22.03	25.23	100.07	3.20
14	3.37	22.03	25.24	99.92	3.21
15	3.64	22.00	25.07	99.91	3.07
16	3.64	22.00	25.08	100.07	3.08
17	1.16	22.63	28.01	99.79	5.38
18	1.16	22.66	28.05	100.02	5.39

Tube Number: 77
File Name: F077S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.42	27.65	99.87	5.23
2	1.16	22.42	27.66	99.90	5.24
3	1.49	22.21	26.76	99.85	4.54
4	1.49	22.21	26.73	99.84	4.52
5	1.86	22.04	26.05	99.94	4.01
6	1.86	22.04	26.06	99.82	4.02
7	2.24	21.94	25.58	99.92	3.64
8	2.24	21.94	25.59	100.16	3.65
9	2.62	21.86	25.21	100.06	3.35
10	2.62	21.86	25.21	99.88	3.35
11	3.00	21.80	24.91	99.92	3.11
12	3.00	21.80	24.90	99.79	3.10
13	3.37	21.75	24.65	99.81	2.90
14	3.37	21.75	24.64	100.04	2.90
15	3.64	21.72	24.49	100.06	2.78
16	3.64	21.72	24.50	100.08	2.78
17	1.16	22.39	27.61	99.82	5.22
18	1.16	22.39	27.59	100.00	5.20

Tube Number: 78
File Name: F078S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.01	26.28	100.15	5.27
2	1.16	21.00	26.28	100.14	5.28
3	1.49	20.79	25.28	99.83	4.49
4	1.49	20.79	25.28	99.75	4.49
5	1.87	20.63	24.58	100.05	3.95
6	1.87	20.63	24.57	99.97	3.94
7	2.25	20.52	24.08	99.83	3.56
8	2.25	20.52	24.05	99.98	3.53
9	2.62	20.44	23.66	99.99	3.22
10	2.62	20.44	23.69	99.88	3.26
11	3.00	20.38	23.42	99.92	3.04
12	3.00	20.37	23.40	100.01	3.02
13	3.38	20.32	23.16	100.08	2.84
14	3.38	20.32	23.14	99.93	2.82
15	3.65	20.29	22.99	100.00	2.70
16	3.65	20.29	22.94	99.78	2.66
17	1.16	20.95	26.21	99.87	5.27
18	1.16	20.97	26.25	99.96	5.28

Tube Number: 78
File Name: F078S0A2
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.73	25.85	99.96	5.13
2	1.16	20.72	25.85	100.03	5.13
3	1.49	20.51	24.90	100.05	4.39
4	1.49	20.51	24.90	100.07	4.39
5	1.87	20.35	24.20	100.01	3.85
6	1.87	20.34	24.19	100.00	3.85
7	2.25	20.23	23.70	100.00	3.47
8	2.25	20.22	23.69	99.97	3.47
9	2.63	20.14	23.33	99.99	3.19
10	2.63	20.14	23.32	100.01	3.18
11	3.00	20.07	23.04	100.05	2.97
12	3.00	20.07	23.04	100.05	2.97
13	3.38	20.02	22.80	99.99	2.78
14	3.38	20.02	22.80	100.01	2.78
15	3.65	19.98	22.64	100.01	2.66
16	3.65	19.98	22.64	100.01	2.66
17	1.16	20.67	25.77	99.99	5.11
18	1.16	20.67	25.80	99.92	5.13

Tube Number: 79
File Name: F079S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.09	26.25	99.95	5.16
2	1.16	21.10	26.24	100.01	5.15
3	1.49	20.89	25.33	99.87	4.44
4	1.49	20.89	25.33	99.93	4.44
5	1.87	20.74	24.68	100.05	3.94
6	1.87	20.74	24.67	100.03	3.93
7	2.25	20.64	24.19	99.79	3.55
8	2.25	20.63	24.19	99.87	3.56
9	2.62	20.55	23.78	99.83	3.23
10	2.62	20.56	23.74	99.94	3.19
11	3.00	20.50	23.52	99.89	3.03
12	3.00	20.50	23.51	99.80	3.01
13	3.38	20.45	23.28	99.95	2.83
14	3.38	20.45	23.29	99.89	2.84
15	3.65	20.42	23.11	100.09	2.69
16	3.65	20.42	23.11	100.08	2.69

Tube Number: 90
File Name: F090S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.74	26.01	100.03	5.27
2	1.16	20.74	26.02	99.98	5.28
3	1.49	20.53	25.05	100.00	4.52
4	1.49	20.52	25.05	100.10	4.53
5	1.87	20.36	24.34	99.99	3.99
6	1.87	20.35	24.34	99.93	3.99
7	2.25	20.23	23.83	100.04	3.60
8	2.25	20.23	23.84	100.09	3.61
9	2.63	20.14	23.48	99.95	3.34
10	2.63	20.13	23.49	100.08	3.35
11	3.00	20.07	23.20	99.96	3.13
12	3.00	20.07	23.19	100.09	3.13
13	3.38	20.00	22.95	99.98	2.95
14	3.38	20.00	22.96	99.96	2.96
15	3.65	19.97	22.79	99.91	2.82
16	3.65	19.97	22.79	99.87	2.82

Tube Number: 91
File Name: F091S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.90	25.71	99.96	4.81
2	1.16	20.90	25.71	100.01	4.81
3	1.49	20.68	24.77	99.95	4.09
4	1.49	20.68	24.78	100.00	4.10
5	1.87	20.52	24.17	100.00	3.65
6	1.87	20.52	24.18	100.09	3.66
7	2.25	20.40	23.65	99.92	3.26
8	2.25	20.40	23.65	99.83	3.25
9	2.62	20.32	23.33	100.04	3.01
10	2.62	20.32	23.33	99.90	3.01
11	3.00	20.26	23.06	100.07	2.80
12	3.00	20.25	23.05	100.06	2.80
13	3.38	20.20	22.79	99.93	2.60
14	3.38	20.20	22.79	99.81	2.60
15	3.65	20.16	22.66	100.01	2.50
16	3.65	20.16	22.67	100.03	2.51

Tube Number: 92
File Name: F092S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.66	25.93	99.92	5.27
2	1.16	20.66	25.94	99.87	5.28
3	1.49	20.46	24.94	99.87	4.48
4	1.49	20.46	24.94	99.97	4.48
5	1.87	20.31	24.21	100.02	3.91
6	1.87	20.31	24.21	99.97	3.90
7	2.25	20.20	23.67	99.92	3.47
8	2.25	20.20	23.68	100.00	3.48
9	2.63	20.12	23.30	100.08	3.18
10	2.63	20.12	23.30	100.09	3.19
11	3.00	20.06	23.02	100.00	2.97
12	3.00	20.06	23.03	99.99	2.98
13	3.38	20.01	22.77	99.91	2.76
14	3.38	20.01	22.78	99.96	2.77
15	3.65	19.98	22.66	99.90	2.68
16	3.65	19.98	22.65	100.08	2.67

Tube Number: 93
File Name: F093S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	20.71	26.15	99.98	5.43
2	1.16	20.77	26.22	100.04	5.45
3	1.49	20.63	25.24	99.92	4.61
4	1.49	20.62	25.24	99.92	4.62
5	1.87	20.48	24.57	100.12	4.09
6	1.87	20.48	24.56	100.12	4.08
7	2.25	20.36	24.07	100.04	3.70
8	2.25	20.36	24.07	99.89	3.71
9	2.63	20.27	23.65	99.90	3.38
10	2.63	20.27	23.66	99.93	3.39
11	3.00	20.20	23.36	100.00	3.15
12	3.00	20.20	23.35	99.85	3.15
13	3.38	20.14	23.12	99.99	2.97
14	3.38	20.14	23.12	99.91	2.98
15	3.65	20.10	22.96	100.09	2.86
16	3.65	20.10	22.96	100.09	2.85

Tube Number: 94
File Name: F09450A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.09	26.54	100.08	5.45
2	1.16	21.09	26.54	99.99	5.46
3	1.49	20.88	25.56	100.08	4.68
4	1.49	20.88	25.58	100.01	4.70
5	1.87	20.72	24.87	100.08	4.15
6	1.87	20.72	24.88	99.89	4.16
7	2.25	20.61	24.38	99.97	3.77
8	2.25	20.61	24.37	100.06	3.77
9	2.62	20.53	23.99	99.90	3.46
10	2.62	20.52	23.98	100.06	3.46
11	3.00	20.46	23.68	99.96	3.22
12	3.00	20.46	23.69	99.79	3.23
13	3.38	20.41	23.43	99.97	3.02
14	3.38	20.41	23.43	99.92	3.02
15	3.65	20.38	23.28	100.05	2.90
16	3.65	20.38	23.28	100.09	2.89
17	1.16	21.06	26.46	99.92	5.40
18	1.16	21.06	26.48	100.14	5.43

Tube Number: 95
File Name: F09550A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.02	26.61	99.95	5.60
2	1.16	21.02	26.61	100.11	5.59
3	1.49	20.81	25.61	99.90	4.80
4	1.49	20.81	25.59	100.02	4.78
5	1.87	20.66	24.87	100.06	4.21
6	1.87	20.66	24.85	99.99	4.19
7	2.25	20.55	24.32	100.00	3.78
8	2.25	20.55	24.33	100.13	3.78
9	2.62	20.47	23.93	100.03	3.46
10	2.62	20.47	23.94	100.08	3.46
11	3.00	20.41	23.64	100.00	3.23
12	3.00	20.41	23.65	99.82	3.23
13	3.38	20.36	23.37	100.05	3.01
14	3.38	20.37	23.38	100.09	3.01
15	3.65	20.34	23.22	99.92	2.88
16	3.65	20.34	23.22	99.84	2.88
17	1.16	21.02	26.55	99.93	5.53
18	1.16	21.02	26.55	99.95	5.53

```
Tube Number:            86
File Name:              F006S0V1
Pressure Condition:  Vacuum
Steam Velocity:         2.0 (m/s)

Data      Vw        Tin      Tout        Ts         To-Ti
 #       (m/s)      (C)       (C)        (C)         (C)

 1       1.16      21.88     23.47      48.72       1.60
 2       1.16      21.88     23.47      48.19       1.59
 3       1.49      21.68     23.09      48.21       1.41
 4       1.49      21.68     23.09      48.26       1.41
 5       1.86      21.52     22.78      48.15       1.26
 6       1.86      21.52     22.78      48.15       1.25
 7       2.24      21.42     22.57      48.67       1.15
 8       2.24      21.42     22.56      48.11       1.14
 9       2.62      21.34     22.40      48.40       1.06
10       2.62      21.34     22.40      48.60       1.06
11       3.00      21.28     22.26      48.58        .99
12       3.00      21.28     22.27      48.81        .99
13       3.43      21.23     22.15      48.23        .92
14       3.38      21.23     22.14      48.86        .92
15       3.65      21.19     22.08      48.77        .88
16       3.65      21.20     22.07      48.58        .88
17       1.16      21.85     23.45      48.18       1.60
18       1.16      21.88     23.47      48.70       1.59
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Tube Number:            06
File Name:              F006S0V1
Pressure Condition:  Vacuum
Steam Velocity:         2.0 (m/s)

Data      Vw        Tin      Tout        Ts         To-Ti
 #       (m/s)      (C)       (C)        (C)         (C)

 1       1.16      22.13     23.75      48.50       1.62
 2       1.16      22.13     23.74      48.32       1.62
 3       1.49      21.92     23.34      48.36       1.42
 4       1.49      21.92     23.34      48.41       1.42
 5       1.97      21.73     22.98      48.50       1.25
 6       1.97      21.72     22.98      48.37       1.26
 7       2.51      21.61     22.75      48.35       1.14
 8       2.51      21.60     22.74      48.30       1.14
 9       3.00      21.52     22.58      48.37       1.06
10       3.00      21.52     22.57      48.45       1.05
11       3.43      21.47     22.44      48.39        .97
12       3.43      21.46     22.46      48.42       1.00
13       3.86      21.41     22.36      48.43        .94
14       3.86      21.41     22.35      48.55        .94
15       4.40      21.36     22.25      48.34        .89
16       4.40      21.37     22.26      48.43        .89
17       1.16      22.11     23.71      48.42       1.60
18       1.16      22.09     23.69      48.37       1.60
```

Tube Number: 96
File Name: F096S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.64	24.18	48.30	1.54
2	1.16	22.63	24.18	48.22	1.55
3	1.48	22.42	23.81	48.51	1.39
4	1.48	22.42	23.81	48.40	1.39
5	1.97	22.22	23.45	48.36	1.23
6	1.97	22.22	23.45	48.55	1.23
7	2.51	22.09	23.19	48.40	1.10
8	2.51	22.09	23.19	48.44	1.11
9	2.99	22.00	23.02	48.33	1.02
10	2.99	21.99	23.01	48.48	1.02
11	3.43	21.94	22.90	48.40	.96
12	3.43	21.94	22.90	48.40	.96
13	3.86	21.90	22.80	48.60	.90
14	3.86	21.90	22.80	48.62	.90
15	4.40	21.86	22.70	48.60	.84
16	4.40	21.86	22.70	48.42	.84
17	1.16	22.58	24.12	48.61	1.53
18	1.16	22.58	24.13	48.37	1.55

Tube Number: 83
File Name: F083S0V1
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.64	24.31	48.36	1.67
2	1.16	22.64	24.30	48.36	1.66
3	1.48	22.42	23.91	48.50	1.49
4	1.48	22.41	23.90	48.54	1.49
5	1.97	22.24	23.56	48.36	1.32
6	1.97	22.23	23.56	48.49	1.32
7	2.51	22.08	23.29	48.44	1.20
8	2.51	22.08	23.29	48.49	1.20
9	2.99	21.99	23.09	48.54	1.10
10	2.99	21.99	23.11	48.46	1.12
11	3.43	21.92	22.98	48.57	1.06
12	3.43	21.92	22.99	48.58	1.06
13	3.86	21.87	22.88	48.59	1.01
14	3.86	21.87	22.88	48.49	1.01
15	4.40	21.82	22.78	48.50	.95
16	4.40	21.82	22.76	48.44	.94
17	1.16	22.53	24.19	48.49	1.66
18	1.16	22.53	24.20	48.33	1.67

Tube Number: 83
File Name: F083S0V2
Pressure Condition: Vacuum
Steam Velocity: 2.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.43	24.10	48.49	1.68
2	1.16	22.42	24.09	48.50	1.67
3	1.48	22.21	23.70	48.51	1.49
4	1.48	22.20	23.69	48.33	1.49
5	1.97	22.03	23.37	48.34	1.33
6	1.97	22.02	23.35	48.33	1.33
7	2.51	21.88	23.09	48.40	1.21
8	2.51	21.88	23.09	48.39	1.21
9	3.00	21.79	22.92	48.53	1.12
10	3.00	21.80	22.92	48.54	1.13
11	3.43	21.73	22.76	48.47	1.02
12	3.43	21.73	22.79	48.45	1.06
13	3.86	21.69	22.69	48.33	1.01
14	3.86	21.69	22.70	48.49	1.01
15	4.40	21.64	22.59	48.54	.95
16	4.40	21.64	22.59	48.36	.95
17	1.16	22.36	24.05	48.55	1.69
18	1.16	22.36	24.02	48.33	1.65

Tube Number: 86
File Name: F086S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.51	27.01	99.89	5.50
2	1.16	21.51	26.97	99.95	5.46
3	1.49	21.31	26.02	100.04	4.71
4	1.49	21.30	26.02	99.76	4.72
5	1.87	21.15	25.30	99.98	4.16
6	1.87	21.15	25.30	99.93	4.15
7	2.24	21.04	24.84	99.98	3.80
8	2.24	21.04	24.83	99.90	3.79
9	2.62	20.96	24.46	99.90	3.50
10	2.62	20.96	24.47	99.96	3.50
11	3.00	20.90	24.18	99.89	3.27
12	3.00	20.90	24.17	99.93	3.27
13	3.38	20.85	23.90	99.90	3.05
14	3.38	20.85	23.91	100.12	3.05
15	3.65	20.82	23.78	100.00	2.96
16	3.65	20.82	23.78	99.92	2.96
17	1.16	21.49	26.96	99.92	5.47
18	1.16	21.50	26.95	100.02	5.45

Tube Number: 06
File Name: F006S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	21.71	27.59	99.92	5.88
2	1.16	21.71	27.57	100.08	5.85
3	1.49	21.51	26.43	99.99	4.92
4	1.49	21.51	26.42	99.99	4.91
5	1.97	21.32	25.49	100.01	4.17
6	1.97	21.32	25.50	99.94	4.18
7	2.51	21.18	24.84	99.97	3.65
8	2.51	21.18	24.88	100.06	3.70
9	3.00	21.10	24.49	100.10	3.38
10	3.00	21.10	24.47	99.98	3.37
11	3.43	21.05	24.21	99.86	3.16
12	3.43	21.04	24.21	99.90	3.17
13	3.86	21.00	23.98	99.97	2.99
14	3.86	21.00	23.98	99.97	2.98
15	4.40	20.96	23.75	99.87	2.80
16	4.40	20.96	23.75	99.90	2.80
17	1.16	21.67	27.54	100.11	5.88
18	1.16	21.70	27.54	100.15	5.85

Tube Number: 96
File Name: F096S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.13	27.65	99.89	5.52
2	1.16	22.13	27.63	99.86	5.50
3	1.49	21.92	26.55	100.07	4.64
4	1.49	21.92	26.55	99.99	4.63
5	1.97	21.74	25.66	99.92	3.92
6	1.97	21.74	25.65	100.04	3.91
7	2.51	21.61	25.01	99.88	3.40
8	2.51	21.61	25.01	99.98	3.40
9	3.00	21.53	24.62	99.87	3.08
10	3.00	21.53	24.62	99.85	3.09
11	3.43	21.48	24.33	99.92	2.86
12	3.43	21.48	24.33	99.98	2.85
13	3.86	21.43	24.09	99.83	2.65
14	3.86	21.43	24.09	99.84	2.66
15	4.40	21.39	23.86	99.99	2.47
16	4.40	21.39	23.86	100.00	2.47
17	1.16	22.13	27.62	100.04	5.48
18	1.16	22.13	27.63	100.08	5.50

Tube Number: 83
File Name: F083S0A1
Pressure Condition: Atmospheric
Steam Velocity: 1.0 (m/s)

Data #	Vw (m/s)	Tin (C)	Tout (C)	Ts (C)	To-Ti (C)
1	1.16	22.72	28.33	99.89	5.60
2	1.16	22.72	28.32	99.96	5.60
3	1.48	22.53	27.24	99.88	4.71
4	1.48	22.53	27.24	100.04	4.72
5	1.97	22.35	26.37	100.02	4.02
6	1.97	22.35	26.37	100.02	4.02
7	2.51	22.22	25.78	99.98	3.56
8	2.51	22.22	25.78	99.92	3.56
9	3.00	22.14	25.43	99.89	3.29
10	3.00	22.14	25.41	99.99	3.28
11	3.43	22.09	25.20	100.02	3.11
12	3.43	22.09	25.21	100.13	3.12
13	3.86	22.05	24.99	99.96	2.94
14	3.86	22.05	24.99	100.08	2.95
15	4.40	22.01	24.77	100.00	2.76
16	4.40	22.01	24.76	99.85	2.75
17	1.16	22.76	28.32	99.98	5.56
18	1.16	22.76	28.32	99.97	5.56

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